NSW Department of Planning and Environment
G.P.O. Box 39
SYDNEY NSW 2001

20th May 2017

Re: Submission Regarding the EIS for the Proposed Narrabri Gas Project (SSD 14_6456)

Dear Sir / Madam,

I am president of the Artesian Bore Water Users Association Inc., and I thank you for this opportunity to present our submission to the Santos Narrabri Gas Project EIS.

Artesian Bore Water Users Association of NSW Inc. (ABWUA) objects to this Narrabri Gas Project (NGP) on many grounds. This EIS is a proponent-driven exercise in spin and misrepresentation. Santos had so many years to get their paid proponents to write this report, and we are given a couple of months to digest it and respond. There are so many flaws in this document that it is hard to know where to begin, or to have time and space to list them all.

Firstly we must point out that Santos starts the EIS with a *blatant* untruth in their introduction. Santos, in the introduction, state that "In addition, the project is not located within a major recharge zone of the Great Artesian Basin." All the CSIRO maps, Geoscience, all GAB mapping, show clearly and irrefutably, that this statement is untrue. I was told by an expert from the Dept., that the entire EIS is therefore invalid, and should be thrown out and have to be re-written, for making such a misleading (and completely untrue) statement at the beginning.

In 2015 ABWUA commissioned a report by SoilFutures Consulting Pty Ltd into the recharge systems and petroleum and gas licenses. (GAB Recharge Systems 2015 – attached). This peer-reviewed report clearly states that:

- In NSW, the main occurrence of recharge > 30mm is in the east Pilliga between Coonabarabran and Narrabri.
  Other proof of the location of the GAB recharge in relation to the Narrabri Gas Project (NGP) is various and comprises CSIRO maps used by both Queensland and NSW State Governments and the Australian Federal Government. Other resources are listed in the reference section of the report which is attached. (Doc. enclosed).

  Other findings in the report include:

- Only 0.2% of the GAB has effective recharge of 30 – 79mm/yr.

- Both the Pilliga and the northern Surat gas fields or licence areas occur in the very limited critical recharge (>30mm) areas of the GAB.

- Excessive draw-down of pressure heads in the recharge zone of the GAB associated with gas extraction, has the potential to reduced pressure heads on artesian waters across much of the GAB, and potentially stopping the free flow of waters to the surface at springs and bores.

- "Drawdown of many hundreds of metres is reported in Ransley and Smerdon (2012) for the northern Surat basin coal seam gas fields where coal seams are being dewatered to release gas." Whereas Santos claim a mere "0.5m drawdown".

So the drilling through the southern recharge of the GAB, *will* destroy the pressure, which allows the groundwater to be brought to the surface. There is much evidence of this in the Queensland gasfields already, where so many bores have failed already.
See report below:

Great Artesian Basin Coordinating Committee - Key Issue 1, Declining Artesian Pressure.

Pressure is a key attribute of any artesian groundwater resource providing a relatively low-cost supply in remote areas. Excessive extraction of water through uncontrolled discharge from artesian bores, both above and below ground level, has resulted in a continuing decline in artesian pressures in parts of the Basin, causing a loss of access to artesian water by an increasing number of water users. Reduced natural discharge in response to declining artesian pressure is also causing detrimental impacts on groundwater-dependent ecosystems (such as mound springs and wetlands) and associated biodiversity and cultural heritage values.
http://www.gabcc.org.au/public/content/ViewCategory.aspx?id=13

Other queries arising from statements in the Introduction to the EIS:

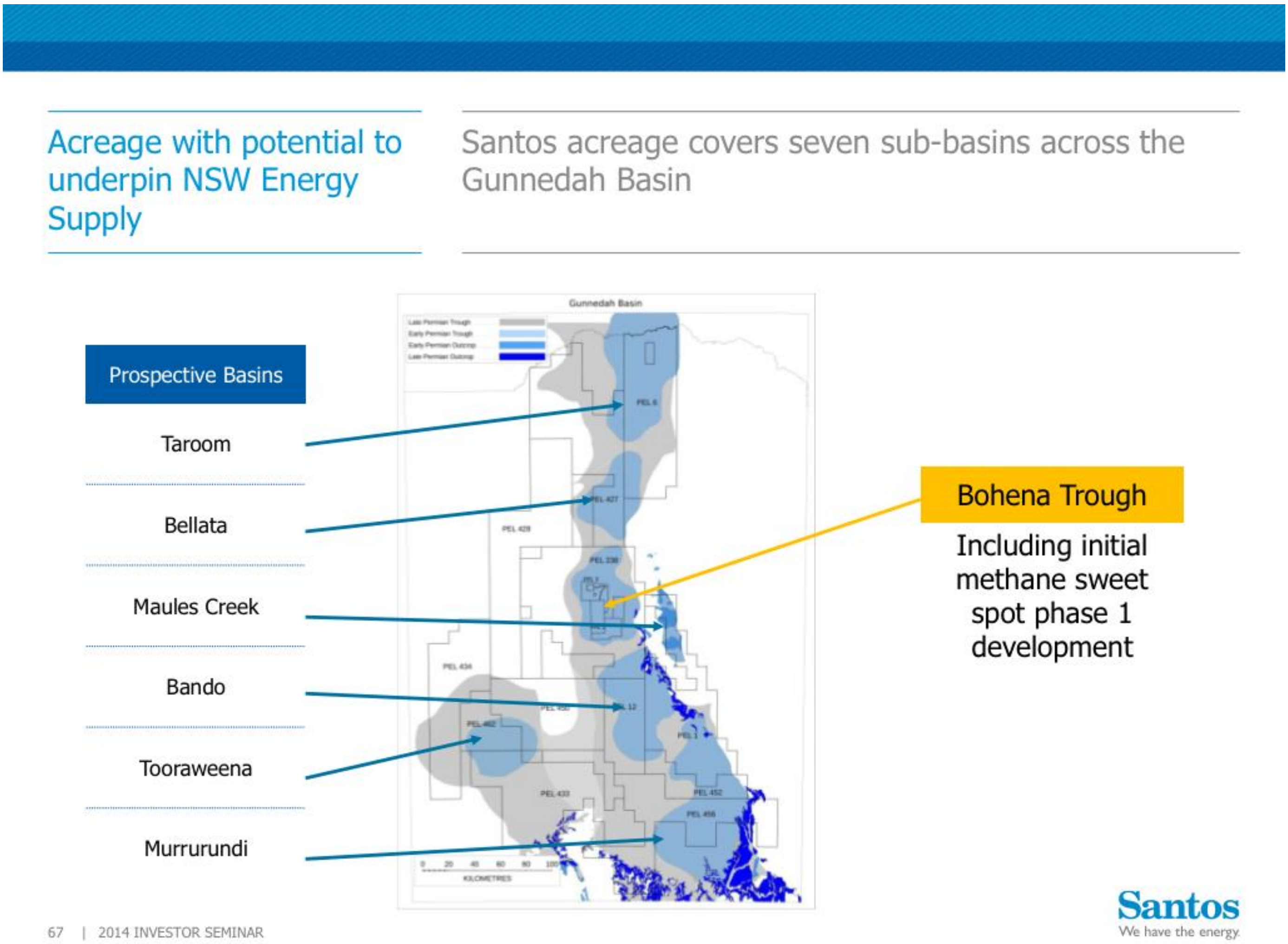
"Due to the geology of the deep coal seams, hydraulic fracturing will not be needed to extract the gas and Santos is not seeking approval to use this technology." Why did Eastern Star Gas (of which Santos was a major partner at the time) need to frack, when they owned the licence – if it was not necessary? Does the fact 'Santos is not seeking approval to use this technology' mean they will guarantee in writing, to never frack, no matter what the circumstances? Will it be written into any sale contract that the purchaser can't frack? I have been told by expert hydrogeologists and groundwater engineers, that ***every*** gas well is fracked ultimately. Some don't need to be fracked immediately, as the gas flows freely at first, but some need to be fracked straight away. But eventually every single well is fracked, to get the best value from the cost of setting up the wells and infrastructure. As one hydrogeologist (and gas well driller) explained to me, "it is like wringing out a sponge - you have to get every last drop out of the seam. It is necessary to make it cost-effective."

Santos also use weasel words such as "we don't *INTEND* to frack…" which leaves them open to later do fracking. Their next statement (after the project gets the "tick the box" that our Member Kevin Humphries assures us it will), would be "Oh, we didn't *INTEND* to frack, but now circumstances have changed and we found that we had to frack to get the gas out."

And this (following) is probably the worst inaccuracy in the EIS:
"The EIS found the project will have minimal risk of impact on agricultural and domestic water sources". Sadly, the Queensland CSG experience has shown this is certainly not the case. So many bores have lost pressure, are burping and bubbling with gas, can be set on fire, or have simply failed altogether. When a bore now fails in Queensland, they simply plug and abandon it, and sink a new bore to a deeper level - which effectively masks the fact that they are depleting and destroying the Basin there.
There is no data base in Qld. of the failed bores, and no publicly available record of how many bores have failed so far. They are hiding all the data and trying to hide the facts, as they don't want people to know.
But the evidence from Queensland shows that even where fracking hasn't occurred, there is clear evidence that there have already been massive impacts on water bores and industries. And now we also have a wealth of evidence from the U.S. that unconventional gas extraction (with or without fracking) damages the other users' water. We now have proof that in relation to the predictions of damage to our groundwater made in previous reports, the impacts are coming much sooner (and worse) than was predicted. https://www.dnrm.qld.gov.au/ogia/surat-underground-water-impact-report

The 'Triple-Stacked' drilling of horizontal coal seam gas wells through the casing of the existing wells, at Dewhurst 13-18H and 31, poses an even greater danger to the Great Artesian Basin and other aquifers than from ordinary wells, as it is very difficult, if not impossible, to seal the junction between the casing and the lateral. When questioned about sealing these junctions, Chief Scientist Professor Mary O'Kane said she had been told by Santos that they had difficulty sealing these junctions known as Kick Off Points (KOPs). It is unfortunately very clear that Santos hold little concern for the pollution of aquifers by either drill fluids or gas escapes and the down draining of aquifers. All gas wells leak in time, industry figures are that 7% leak immediately, and within 20 years, 30% leak. As Santos will be long gone by then, who will bear the future cost of rehabilitating the corroding and crumbling wells, that have lost their integrity?

Santos have stated publicly that this Narrabri Gas Project is just the beginning. They have stated to their shareholders and on their website, that their plan to drill 850 wells across the pristine Pilliga Forest, the largest inland forest left in NSW, and the recharge zone for the Great Artesian Basin, is just the start. (See doc below). They intend to spread out across our most productive farmland, with clear plans for a massive gasfield – tens of thousands of wells - right across the area shown in their map below. And that is just for starters.



ABWUA has been instrumental in the continuation of GABSI, which is the single greatest thing that has happened to the GAB. For many years, ABWUA assisted with this capping and piping scheme, to save the groundwater that was being wasted through free-flowing bores, and to restore the pressure to the GAB (which was failing). GABSI was a proven scheme that was working, pressure was returning to the system, and bores which had not flowed for many years, suddenly started flowing again. Through continued lobbying for funding, GABSI has recently been renewed; it was announced last week that the federal government has renewed GABSI for phase 5.

Information on GABSI is available at http://www.water.nsw.gov.au/water-management/water-recovery/cap-and-pipe-bores

“Great Artesian Basin Sustainability Initiative

The Cap and Pipe the Bores program is part of the Great Artesian Basin Sustainability Initiative (GABSI), jointly funded by the Australian and NSW governments. GABSI phase 1 was implemented between 1999 and 2004 with $25 million funding. Phase 2 built on this with $32 million funding from July 2004 until June 2009. DPI Water has targeted remaining free flowing bores through the Cap and Pipe the Bores program under GABSI phase 3, which finished in June 2014.

Some of the savings made under GABSI include:

Achievements

In the past, up to 95 per cent of artesian water was being wasted through evaporation and seepage. Today, the Cap and Pipe the Bores program has improved water supply through the following achievements:

- saving 78,500 ML of water every year
- supplied approximately 4.2 million ha with permanent, reliable, efficient and strategically located watering points
- controlled 398 free flowing bores
- removed over 10,000 km of bore drains
- installed 18,000 km of piping
- improved water use efficiency and reduced water wastage
- improved water quality for stock and domestic use
- increasing artesian pressure, increasing access to water
- reducing salt discharge by 62,800 tonnes every year
- reducing greenhouse gas emissions by 41,600 tonnes every year
- assisted land managers to achieve more sustainable property and stock management.

Increases in artesian bore pressure are being observed in many areas as a result of capping and piping. The program is achieving many other landscape benefits such as improving biodiversity conservation and feral animal control."

Will the government then please explain why, when all these savings are applauded as benefits to the environment, can Santos now threaten to undo all the good work that has been achieved? Well over half a billion dollars of both the State and Federal governments and the individual landholders, stands to be wasted, as CSG mining does the exact opposite of what GABSI is doing. GABSI restores the pressure, and saves the wastage of finite artesian water; CSG mining has to DE-PRESSURISE and drain the water from the coal seams (and lower the water table).

It has become evident from the Queensland experience that Santos WILL cause a lowering of the water table. This is incontestable as they dewater the aquifers to get the gas – and they have admitted that. As has the National Water Commission.

They have no answer to what they propose to do with the salt they will bring to the surface. Something GABSI was designed to do, was to reduce the salt brought to the surface. All Santos has said is that they will bury it in some as yet unknown landfill. (See attached paper on problems with salt, by geochemist John Polglase).

Current status of GABSI:

Barnaby Joyce announces an extra $8m in federal funding for GABSI 5.
http://minister.agriculture.gov.au/joyce/Pages/Media-Releases/$8-million-top-up-to-support-water-management-in-the-Great-Artesian-Basin.aspx

The Office of Water has stated that bores that impact on springs will be focussed on. 20 – 30 of these bores will be done in the next 3 years.

The government can't afford to cap the less than 250 bores which are still uncapped in NSW alone. Who will ever be able to cap thousands of bores when Santos has long gone and they all need rehabilitating? 7% of bores fail initially, 30% within 20 years and 100% within 100 years. Bores do not last 'forever' as stated by Santos. Concrete and metal do not have a perpetual lifespan.

This damage is permanent. Over time it will be like a pincushion with rusting pins. Who is liable for capping them? Will it be the landowner, and taxpayer – as with GABSI?

Australia is the driest inhabited continent on earth. How can we allow an industry that states 'that to get to the gas it dewaters the aquifer'.

The GAB lies under 22% of Australia. Is it worth the risk?

Water and air are the most valuable things on this planet. How can we risk them?

The GAB is not alone. In fact, worldwide, for most groundwater aquifer systems employed for agriculture:

a. recharge fluxes were over-estimated;
b. reservoir volumes were over-estimated; and
c. extraction volumes were under-estimated.

In other words, over 3-4 decades, most aquifer management (if any) resulted in unsustainable outcomes. The classic example is the High Plains Aquifer in the USA. Equally, with exponential world population growth and exponential domestic reliance upon groundwater, it does not bode well for the health of the remaining 'fossil' systems. Sadly, the enduring and increasing number of 'water conflicts' is an indicator of where we are all headed.

Thank you for the opportunity to present this submission. I have so many other points I would like to raise, so much evidence of so many things wrong with this NGP – but I hope you will give us the opportunity to provide further information later. We are waiting on some vital reports, which are not yet completed, and which will form part of our submission. As I requested in writing to your Department earlier, I would appreciate presenting this information and these reports to you, at a later date.

Yours sincerely,

Anne Kennedy
President ABWUA

Some links:
http://player.vimeo.com/video/102105908
Interview with Professor Ingraffea on well integrity failure

http://psehealthyenergy.org/site/view/1233
Comprehensive list of peer-reviewed papers on unconventional gas development.

http://endocrinedisruption.org/chemicals-in-natural-gas-operations/introduction
TEDX info on endocrine disruption

https://www.youtube.com/watch?v=gz2mq5GYnR0
Dr Mariann Lloyd-Smith's address at Lismore on risks of CSG (and exposes the myths)
(Documents showed they use 18,500 kilograms of chemicals per well)

https://www.youtube.com/watch?v=Kvfzz7_nbqs&feature=youtu.be
Dr Geralyn McCarron on health impacts

http://www.couriermail.com.au/news/opinion/the-environment-deserves-more-than-this-drop-in-a-bucket/story-fnihsr9v-1227027256382?nk=3f4a84942d7e4ccf4baff87e2585f053
Tom Crothers, an independent hydrology consultant and a former general manager of Water Planning and Allocation for Queensland - tells of the enormous destruction to the GAB from mining.

http://csgscienceforum.com/event-videos/
CSG Science Forum (and link to Professor Ingraffea's video)

http://www.propublica.org/article/new-study-predicts-frack-fluids-can-migrate-to-aquifers-within-years
Study on migration of fracking fluids to aquifers

https://www.youtube.com/watch?v=W8qs5HQ6jgs
Professor Ingraffea dispelling myths re fracking

http://www.globalpossibilities.org/usgs-finally-admits-that-fracking-causes-earthquakes/

Groundwater depletion: A global problem

Leonard F. Konikow · Eloise Kendy

Keywords Over-abstraction · Groundwater managment · Groundwater development · Groundwater depletion

Introduction

In the past half-century, ready access to pumped wells has ushered in a worldwide "explosion" of groundwater development for municipal, industrial, and agricultural supplies. Globally, groundwater withdrawals total 750–800 km^3/year (Shah et al. 2000). Economic gains from groundwater use have been dramatic. However, in many places, groundwater reserves have been depleted to the extent that well yields have decreased, pumping costs have risen, water quality has deteriorated, aquatic ecosystems have been damaged, and land has irreversibly subsided.

Groundwater depletion is the inevitable and natural consequence of withdrawing water from an aquifer. Theis (1940) showed that pumpage is initially derived from removal of water in storage, but over time is increasingly derived from decreased discharge and/or increased recharge. When a new equilibrium is reached, no additional water is removed from storage. In cases of fossil or compacting aquifers, where recharge is either unavailable or unable to refill drained pore spaces, depletion effectively constitutes permanent groundwater mining. In renewable aquifers, depletion is indicated by persistent and substantial head declines.

Excessive groundwater depletion affects major regions of North Africa, the Middle East, South and Central Asia, North China, North America, and Australia, and localized areas throughout the world. Although the scope of the problem has not been quantified globally, on-going analysis by the senior author indicates that about 700–800 km^3 of groundwater has been depleted from aquifers in the US during the 20th century. One of the best documented cases is the 450,000 km^2 High Plains aquifer system in the central US, where the net amount of water removed from storage during the 20th century was more than 240 km^3—a reduction of about 6% of the predevelopment volume of water in storage (McGuire et al. 2003). In some of the most depleted areas, use of groundwater for irrigation has become impossible or cost prohibitive (Dennehy et al. 2002).

In some cases, removing the most easily recoverable fresh groundwater leaves a residual with inferior water quality. This is due, in part, to induced leakage from the land surface, confining layers, or adjacent aquifers that contain saline or contaminated water. In coastal areas, where many of the world's largest cities are located, the available volume of fresh groundwater is reduced by seawater intrusion and upconing, which in turn are caused by head declines in the aquifer.

As depletion continues worldwide, its impacts worsen, portending the need for objective analysis of the problem and its possible solutions. This essay examines future options for evaluating and managing groundwater depletion in a changing physical and social landscape.

Quantifying the magnitude of depletion

In general, the magnitude of depletion is rarely assessed and poorly documented, particularly in developing countries and in humid climates. As a necessary precursor to addressing the problem, future efforts will be directed toward developing and refining methods of quantifying depletion.

Groundwater depletion can be viewed from two different perspectives. In one, depletion is considered literally and simply as a reduction in the volume of water in the saturated zone, regardless of water quality considerations. A second perspective views depletion as a reduction in the usable volume of fresh groundwater in storage. For example, seawater intrusion in a coastal aquifer may represent a substantial depletion with respect to water quality, but result from only a trivial depletion in the total volume of fluid in the subsurface. In either case, tracking and estimating the magnitude of depletion is not simple and straightforward, in large part due to a sparsity of relevant data on subsurface conditions and uncertainty in interpreting available data.

Some causes and impacts of groundwater depletion are neither obvious nor easy to assess. For example, groundwater pumped from confined aquifers may be largely derived from leakage from adjacent confining beds, but depletion of low-permeability layers is difficult to estimate, rarely monitored, and usually overlooked. Likewise, lowered water tables may make groundwater less available to phreatophytes and reduce groundwater discharge to springs, streams, and wetlands (Fig. 1). Where a stream is hydraulically connected to an aquifer, streamflow may be reduced by decreasing groundwater discharge into the stream and/or by inducing seepage from the stream into the aquifer. In rivers already stressed by excessive surface-water diversions, it is difficult to distinguish the component of streamflow depletion attributable to reduced baseflow from groundwater discharge.

The most direct way to estimate the volume of water depleted from an aquifer is to integrate maps of head changes over the aquifer area. The resulting aquifer volume is multiplied by an appropriate storage coefficient to compute the corresponding volume

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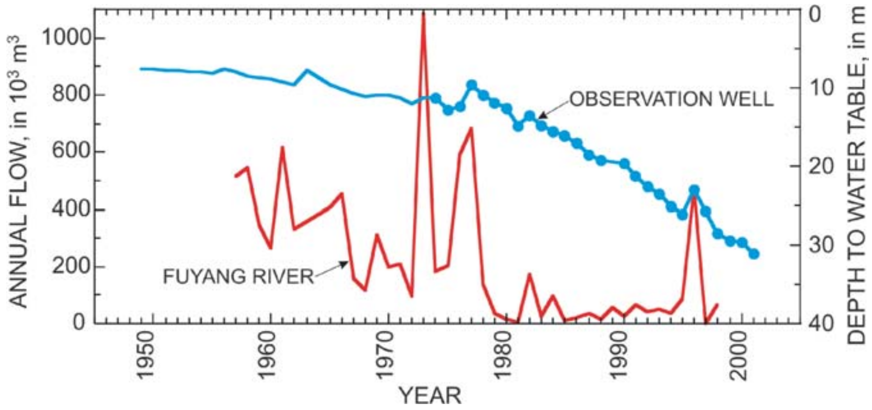

Fig. 1 Stream and well hydrographs from North China Plain showing evidence of reduced streamflow caused by groundwater depletion (groundwater levels prior to 1974 from simulation model calibrated by Kendy 2002)

of water. McGuire et al. (2003) used this approach to estimate depletion in the High Plains aquifer in the USA. Future improvements in collection and telemetry of water-level data, data base management systems, and networking of information systems will likely make it easier to map water-level changes in the future.

Numerical simulation models commonly are used to compute water budgets of regional aquifer systems. If a model is developed using technically sound hydrogeologic judgment and is reasonably well calibrated for both predevelopment and developed conditions, then its output provides estimates of the rate of depletion. In the future, well-calibrated three-dimensional models will be available for more aquifer systems, making it easier to track and predict changes in the volume of groundwater in storage.

Land subsidence can result from irreversible compaction of low-permeability materials in or adjacent to the developed aquifer as fluid pressure declines because of groundwater withdrawals. Extensive subsidence has been well documented in Mexico City, Bangkok, Shanghai, and elsewhere. In confined aquifer systems subject to large-scale overdraft, the volume of water derived from irreversible aquitard compaction is essentially equal to the volume of land subsidence and typically can range from 10 to 30% of the total volume of water pumped (Galloway et al. 1999). Because the extent and magnitude of subsidence can be mapped accurately using a variety of techniques, the minimum magnitude of groundwater depletion can be estimated from the observed extent (and volume) of subsidence.

Although confining units are not usually envisioned as sources of groundwater supply, drawdown in aquifers induces leakage from adjacent confining units. Slow leakage over large areas can result in the confining units supplying most of the water derived from pumping a confined aquifer. For example, Bredehoeft et al. (1983) analyzed the deep, confined Dakota sandstone aquifer in South Dakota, north-central USA, and concluded that "most of the water released from storage in the system since development began has come from the confining beds." This type of groundwater depletion, which affects water quality as well as quantity, will likely garner more attention in the future.

Geophysical gravity methods offer a means to estimate changes in subsurface water storage directly by measuring changes in the Earth's gravitational field (Pool et al. 2000; Hoffman this issue). This method was applied to the Tucson Basin in southern Arizona, USA, for the period 1989–1998 (Fig. 2). In the future, sequential gravity surveys may be conducted from satellites to measure changes in groundwater storage efficiently and accurately over large regions. This technique has the potential to offer near-real-time monitoring and assessment of subsurface hydrologic changes, to which water managers can respond accordingly.

Groundwater depletion and global climate change

Global climate change will profoundly affect hydrologic systems worldwide. Glacial melting and increasing ocean temperatures lead to sea-level rise. On the continents, the frequency and severity of floods and droughts are expected to increase, while higher temperatures will reduce winter snowpack and hasten spring snowmelt from mountainous areas. Unchecked, groundwater depletion can exacerbate the impacts of these changes; conversely, controlled management of groundwater depletion can contribute to their mitigation.

Assuming that the volume of groundwater depleted during the past 100 years is much greater than can be accounted for by non-transient increases in volumes of water stored in soil, natural channels and lakes, or the atmosphere, then the ultimate sink for the "missing" groundwater is the oceans. Worldwide, the magnitude of groundwater depletion from storage may be so large as to constitute a measurable contributor to sea-level rise. For example, the total volume depleted from the High Plains aquifer equates to about 0.75 mm, or about 0.5%, of the observed sea-level rise during the 20th century. Reducing future groundwater depletion (and increasing groundwater storage) can help in a small way to reduce future sea-level rise.

Historically, society's response to floods and droughts has been to impound surface water in reservoirs, and to release it as needed. However, a dearth of geologically suitable locations for new dams, combined with increased awareness of their ecological consequences, will hinder this response to future hydrologic extremes, even as their frequency and intensity increase. Long-term temperature rises will increase the need to store water for distribution over a longer dry season (Service 2004). In some areas, an integrated solution can be achieved by artificially recharging excess runoff, when available. Thus, depleted aquifers can be transformed into underground "reservoirs" to supplement the flood- and drought-buffering capacity of existing surface-water reservoirs.

Management solutions and challenges

Societies respond to water-resource depletion by shifting management objectives from locating and developing new supplies to augmenting, conserving, and reallocating existing supplies (Molle 2003). At the same time, societal objectives are evolving to value water for nontraditional uses, such as maintaining instream flows for aquatic ecosystems. Future groundwater management will have to address these multifaceted challenges.

Augmenting supplies can mean improving water quality or increasing water quantity. Depletion due to quality considerations can often be overcome by treatment, whereas large volumetric depletion can only be alleviated by decreasing discharge or increasing recharge. Artificial recharge of stormflow and treated municipal wastewater, for example, has successfully reversed groundwater declines. In the future, improved infiltration and recharge technologies will be more widely used to maximize the capture of runoff and treated wastewater.

Conserving groundwater by reducing pumpage can be accomplished through administrative, legislative, or management con-

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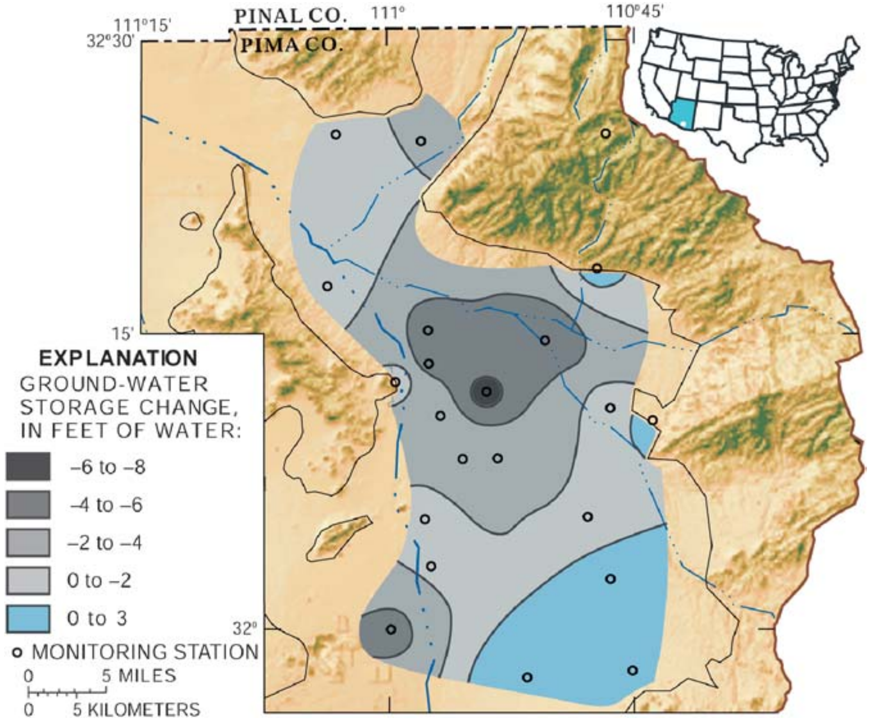

Fig. 2 Change in groundwater storage in the Tucson Basin, southern Arizona, 1989–1998, estimated using gravity methods (modified from Pool et al. 2000)

trols, including economic incentives to reduce demand. It is important to target reductions that actually save water. In agricultural areas, for example, improved efficiency is sometimes sought through lining irrigation canals to reduce seepage. But this approach saves no water if the leaky canals are themselves a major source of recharge to the underlying aquifer, as in the North China Plain (Kendy et al. 2003). If on-farm efficiency gains in saving water are used to irrigate additional land, there will be no overall reduction in water consumption.

Reallocating water resources will play an increasingly important role in groundwater management. Water markets, leasing, trading, and other mechanisms can move limited water from lower to higher productivity sectors, as an alternative to further depletion.

Effective reallocation requires rules to ensure fairness and minimize damages. When large-scale groundwater development began, no institutional mechanisms were in place to control the amount of withdrawals. In contrast to large-scale surface-water systems, which are centrally managed, groundwater supplies were mostly "managed" by individual users. Thus, groundwater development has been largely unregulated, even in many water-scarce areas.

Decentralized management has resulted in a lack of coordination between surface- and groundwater use, despite their vital physical connection. Efficient reallocation requires that groundwater and surface water be managed conjunctively. However, the transition to coordinated regulation can be extremely difficult, as in the Snake River basin of Idaho, northwestern US, where 750 farmers, businesses, and cities recently were ordered to shut down 1,300 wells to restore reduced spring discharge. Up to 450 km^2 of farms, more than 125,000 dairy cattle, several food processing plants, and 14 cities are affected (Barker 2004). In the future, as today, efforts to counter groundwater depletion will be complicated by competing demands on the resource.

Reallocation between economic sectors provides opportunities to optimize conjunctive use. Optimization methods may be used to position pumping centers to maximize withdrawals while minimizing detrimental effects such as stream depletion and well interference. This may lead future water managers to implement appropriation zoning or to require well permits in which allowable pumping rates vary with location because of hydrogeologic properties, distance from boundaries, and unit responses of surface water.

Some regions, particularly in semi-arid and arid climates, may follow the lead of Saudi Arabia, which abandoned its goal of grain self-sufficiency through irrigated agriculture when groundwater mining could not be sustained. In other areas, large-scale water transfer projects might maintain activities and populations that depend on or benefit from the depletion of groundwater resources, even at the expense of environmental impacts in the water-exporting basin.

"Virtual" water imports and exports in the form of grain represent a global response to regional groundwater depletion. For example, analyses of projected water supply and demand scenarios indicate that conventional approaches of augmenting and conserving irrigation water are insufficient to sustain agricultural water use on the North China Plain. Instead, Yang and Zehnder (2001) suggest reallocating irrigation water to urban and industrial use, retiring irrigated land, and importing grain. Ultimately, global reduction in groundwater depletion rates will likely translate to reduced crop production.

Managers of both surface and groundwater will face new challenges of fulfilling not only the traditional objectives of securing water supplies, but also of improving and protecting ecological health, while facing greater climatic fluctuations and population pressure. To achieve consensus, managers must balance the competing needs of people, industry, agriculture, and the environment. At present, many developed countries that place high value on ecological health of springs, wetlands, and streams have the ability to engineer solutions to help meet these complex challenges. In developing countries, where the livelihoods of millions of poor people may depend on unsustainable groundwater withdrawals, water managers face additional complexities that are not amenable to engineering solutions alone. In the future, the pressure of increasing populations worldwide may foster greater acceptance of groundwater depletion, regardless of a nation's development stage.

In the next few decades, groundwater depletion will likely continue to grow, but at a reduced rate. The change in trend is already in evidence in several depleted aquifers in the western US, and results in large part from positive management actions, but also to some degree from the tendency towards self-limitation of depletion imposed by hydraulic and economic constraints.

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Although hydrogeologic understanding of an aquifer system is a valuable component of groundwater management, it cannot by itself define policy. DuMars and Minier (2004) argue that "only a knowledgeable, thoughtful democratic society can ultimately respond to issues of policy." The challenge for hydrogeologists is to develop and apply innovative technical approaches, built upon a solid scientific foundation, that credibly inform society of the impacts and alternatives to groundwater depletion.

Acknowledgements We appreciate the helpful review comments by W.M. Alley and S.A. Leake (U.S. Geological Survey), T.S. Steenhuis (Cornell University), Tushaar Shah (International Water Management Institute), and M.E. Campana (University of New Mexico)

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Symptomatology of a gas field

An independent health survey in the Tara rural residential estates and environs

Photo courtesy local resident

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EXECUTIVE SUMMARY

This report documents an investigation during February and March 2013 by a concerned General Practitioner, in relation to health complaints by people living in close proximity to coal seam gas development in SW Queensland.

Thirty -five households in the Tara residential estates and the Kogan/Montrose region were surveyed in person and telephone interviews were conducted with three families who had left the area. Information was collected on 113 people from the 38 households. Of these, 17 were children 5 years of age or less, 31 were children aged between 6 and 18, and 65 were adults aged between 19 and 82. 58% of residents surveyed reported that their health was definitely adversely affected by CSG, whilst a further 19% were uncertain. The pattern reported was outside the scope of what would be expected for a small rural community. In all age groups there were reported increases in cough, chest tightness, rashes, difficulty sleeping, joint pains, muscle pains and spasms, nausea and vomiting. Approximately one third of the people over 6 years of age were reported to have spontaneous nose bleeds, and almost three quarters were reported to have skin irritation. Over half of children were reported to have eye irritation.

A range of symptoms were reported which can sometimes be related to neurotoxicity (damage to the nervous system), including severe fatigue, weakness, headaches, numbness and paraesthesia (abnormal sensations such as pins and needles, burning or tingling). Approximately a third of the all the 48 children to age 18 (15/48) were reported to experience paraesthesia. Almost all the 31 children aged 6-18 were reported to suffer from headaches and for over half of these the headaches were severe. Of people aged 6 years and over, severe fatigue and difficulty concentrating was reported for over half. Parents of a number of young children reported twitching or unusual movements, and clumsiness or unsteadiness.

This unfunded study is limited in terms of what can be concluded and does not claim to be without methodological problems. However what it does do is highlight the basis for serious concerns of the residents and the need for the Queensland government to fund a comprehensive epidemiological investigation of the problem.

No baseline air or water monitoring or baseline health studies were done prior to the Queensland Government permitting the widespread development of the CSG industry in close proximity to family homes. No ongoing health study or surveillance and no ongoing testing to monitor chronic exposure levels is in place. This is clearly unacceptable.

The rural residential estates near Tara are the most densely settled area in Australia to have seen intensive CSG development. Since 2008, the people of these estates have informed successive Queensland Governments of their health problems. Their reports of ill health have been trivialised and ignored. The recent report released by the Queensland Government following their investigation into the health impacts near Tara was so inadequate and flawed that it has done little to alleviate concerns.

The Queensland government undertook minimal non-systematic environmental sampling, and relied mainly on inadequate industry commissioned data. The investigation of patient symptoms was grossly underfunded and understaffed, with no medical staff actually visiting the site. Only 15 people were examined clinically. Positive findings of volatile chemicals were dismissed, despite the fact they are potentially capable of causing health impacts, especially over long periods of time.

The state government must take its responsibility for the health of these citizens seriously, and the federal government must develop federal legislation to protect public health from CSG impacts.

Recommendations are:

1) A fully funded comprehensive medical assessment of residents currently living in proximity to unconventional gas development should be carried out as a matter of urgency.
2) The planning and urgent implementation of fully funded, long term epidemiological studies is essential to track the health of people exposed to CSG over the next several decades. This must include workers in the industry as well as people who may already have left the area because of health concerns.
3) Health impact assessments must be an integral part of any and every unconventional gas development. No new permit should be issued without one, and health impact assessments should be carried out for every development already in place.
4) Comprehensive air and water monitoring (an open, ongoing and unlimited information loop) is essential. If we are looking at possible non beneficial human health impacts we need to look at all the gases and volatiles both natural and derived emitted via well drilling, gas and pipeline valves, leaking wellheads, flaring, and other processes involved in gas collection/purification/refining to export specifications. This monitoring is urgently required. It must be independent, unbiased, fully funded and available for public scrutiny preferably in real time and in electronic form.
5) Gas companies must be required to fully and openly disclose in a timely manner, all chemicals, and all quantities of chemicals, used or planned to be used for drilling, fracking, cleaning, dehydration, and other processes at every gas facility. All historical results they have of analyses of air, soil and water should be available for public scrutiny.
6) The federal government must develop legislation, a unified standard, to protect public health across Australia from the impacts of unconventional gas development and other extractive industries.
7) There must be open, fully informed, public debate on the future of the unconventional gas industry in Australia.

ACKNOWLEDGEMENTS
I would like to thank the residents of the Tara estates and surrounding areas for their trust and cooperation in completion of this survey which was, for very private people, at times intrusive and distressing. I sincerely hope this study will help to inform the wider community and highlight the basis of your serious concerns.

ABSTRACT

The unconventional gas industry has been allowed rapid, unprecedented expansion in Queensland within recent years with little regard to the public health consequences. The people of the remote rural residential estates on the Western Downs near Tara in Queensland are suffering from the side-effects of the industry. Despite their pleas over the past few years to successive Queensland Governments, as illustrated in the recently released Queensland Government health report into the effects of CSG in the Tara region, their reports of ill health have been trivialised or ignored.

Conversely this study found a pattern of symptoms which is extremely concerning. In particular a high percentage of the residents surveyed had symptoms which could relate to neurotoxicity. These included tingling, paraesthesia[i], numbness, headaches, difficulty concentrating and extreme fatigue. Of particular concern was the high percentage of symptomatic children, with paraesthesia being reported in approximately a third (15/48) of children to age 18, and headaches being reported in more than 70% (36/48). These symptoms deserve further investigation, something which has not been done adequately to date. If these symptoms are caused by living within a gas field, there are serious implications not only for this community but for many more across Australia. If the health implications of the unconventional gas industry continue to be ignored and the industry is allowed to develop along its current path, the potential exists for serious and widespread harm to human health across Australia.

[i] Paraesthesia refers to a burning or prickling sensation that is usually felt in the hands, arms, legs, or feet, but can also occur in other parts of the body.

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INTRODUCTION

I am a general practitioner who has been living and working in suburban Brisbane for the past 25 years. As little as 18 months ago, I was oblivious to the concept of unconventional gas extraction. Having been made aware of impacts of CSG and Shale gas developments overseas, I took an increasing interest in what was happening in rural Queensland, and I became increasingly concerned. I began following the story of the CSG industry in the Tara area and visited the region on several occasions as part of a community initiative called "Bridging the Divide".[ii] This put into sharp focus the problems being experienced by people living within Queensland's gas fields and lead to me undertaking this study.

BACKGROUND

Within the past few years the unconventional gas industry, particularly coal seam gas (CSG) has been permitted to develop with remarkable rapidity across rural Queensland. Little or no consideration has been given to how this will affect public health. No baseline health studies were done prior to the Queensland Government permitting the widespread development of this controversial industry in close proximity to family homes. No ongoing health study or surveillance is in place. No baseline air or water monitoring was done and no ongoing testing to monitor chronic exposure levels has taken place.

As reported in The Courier Mail on February 11th 2013, the approvals for the coal seam gas developments were controversial and were pushed through despite the public servants responsible for drafting the environmental response stating clearly that serious harm would ensue.[1]

The following is just one of 26 objections made by Simone Marsh, the public servant in charge of drafting the environmental response from the Queensland's Government Coordinator-General, to the process of approving the Santos GLNG project:

"It is clear the project's activities will lead to wide-spread, serious environmental harm and material environmental harm, as defined by the Environmental Protection Act, both during and following the removal, transportation and processing of coal seam gas,"[1]

The Courier Mail also reported that the EIS assessment team responsible for vetting the safety of these multibillion dollar projects were given a physically impossible task.

DERM director (EIS assessment) Stuart Cameron, May 4, 2010 responded to a request for draft conditions to be submitted in three days:

[ii] Bridging the Divide is a city-country communication and support network involving health and social justice issues.

"I have consistently been advised by DIP (Department of Infrastructure and Planning) the QGC was down the track and that DIP had not even started writing their report. We have had no warning for this sudden request for immediate provision of QGC conditions or any notice of a meeting tomorrow. In addition we have the APLNG comment on their EIS due today for which we were given less than four weeks to deal with 10,000 pages. Once again I am faced with a physically impossible request along with the other 80 EIS projects that are starting to slip."[1]

People who owned their own home and land did not have protection in legislation or the right to prevent gas companies coming onto their property. Their only legal recourse was to negotiate compensation. Communities had no choice.

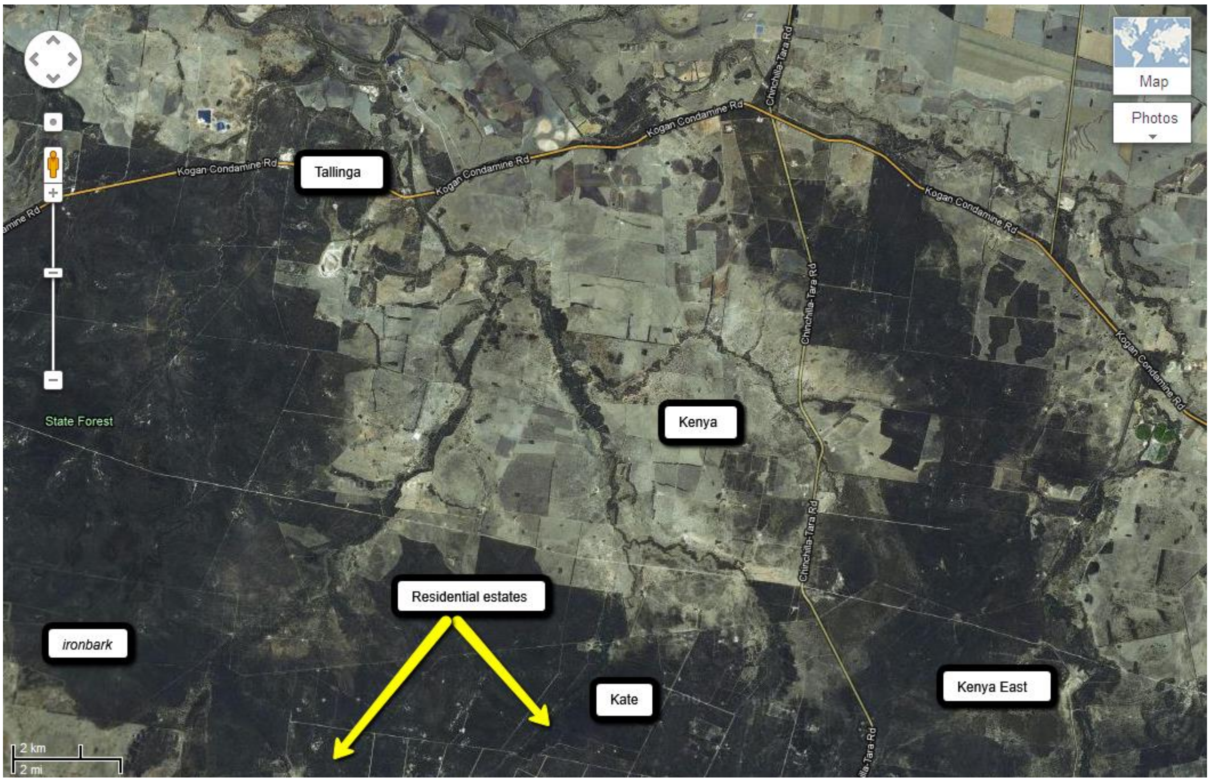
The circumstances surrounding the permitting of the coal seam gas developments have now been referred to the Crime and Misconduct Commission. The alleged inadequacies in the assessment process for CSG projects highlight the failure of state governments to put in place adequate protections for communities and the environment. No health impact assessment was undertaken for the CSG developments approved initially and no health impact assessment has been required for developments since.

TARA CASE STUDY

The rural residential estates outside Tara in Queensland's Western Downs are surrounded by the infrastructure of the coal seam gas industry and unconventional gas development. Since 2008, the people of these estates have been trying to draw the attention of successive Queensland Governments to their health problems.

It is approximately 70km from Chinchilla in the north to Tara in the south along the Chinchilla-Tara road. Major gas fields and infrastructure are located in the region between Chinchilla and Tara. They are under the control of Queensland Gas Company (QGC), British Gas, Origin and others. The Tara rural residential estates are located in the same area with most of the estates lying south of the immense Kenya gas field with its evaporation ponds, dehydration plants, compressor stations and associated infrastructure.

The Talinga gas field is to the North West, Ironbark to the West and Kenya East to the east. While hundreds of gas wells surround the residences, the Codie, Kate and Jake fields are actually situated within the Tara estates.



LAYOUT OF GAS FIELDS IN RELATION TO TARA RESIDENTIAL ESTATES
@Google 2013

GIANT KENYA HOLDING PONDS
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TALINGA GASFIELD, COMPRESSOR AND INFRASTRUCTURE
(NORTH OF RESIDENTIAL ESTATES)
@Google 2013

These major projects are often described as "development"[iii] but their introduction has not brought better quality of life or additional services to the local people. The residents live on rural blocks ranging in size typically from 30 to 250 acres. They are surrounded by the infrastructure of the gas industry. There are no shops, petrol stations, schools or other basic facilities. The nearest doctor is in Tara which is an approximately 70km round trip. Residents habitually travel to medical facilities in Chinchilla, Dalby and Toowoomba where the regional base hospital is located.

Beyond the estates towards Kogan and Montrose, there has also been rapid CSG development on large acreage agricultural blocks.

In June 2012 the Queensland Government finally committed to investigate the growing health complaints of residents. On 21st March 2013 Queensland Health issued a report titled 'Coal seam gas in the Tara region: summary risk assessment of health complaints and environmental monitoring data report.'[2]

Between June 2012 and March 2013, no doctor employed by the Queensland Government visited the residential estates to speak to the residents. The township of Tara was the closest that the Queensland Government doctors got to the source of the

[iii] People who express concerns about the unconventional gas industry are often referred to as 'anti-development'.

health complaints. Considering they were investigating the health impacts of living in a gas development it is somewhat surprising that no on-site visits were made.

In the nine months available to them, the Queensland Government Departments failed to establish a comprehensive, systematic long term testing regime to monitor potential chronic exposure to air or water borne toxins. Instead they commissioned QGC, the gas company at the heart of the residents' health complaints, to undertake testing, creating a clear conflict of interest. Sampling, which occurred as one off events at nine residences, was entirely inadequate in scope and duration. Importantly, what is missing are analyses of the gases produced in the localities concerned by flaring, well leakages and pipeline venting.

There is evidence of irregularities in the documentation accompanying the test samples. On the chain of custody for one site the start time was documented as 09:37 and finish time 07:30. In that particular case, the family left home shortly after the QGC representatives arrived. When the family returned at lunchtime, the QGC representatives had gone taking all their equipment with them. Sampling which is documented as lasting 22 hours could only have lasted for approximately 1-3 hours.

Apart from a limited number of passive samplers, in the 9 months of the investigation, the only other air testing employed was random 30-60 second Summa canisters. These tests were undertaken by the resident themselves.

People who believed they were impacted by CSG were told to phone a 13 HEALTH number or report to their local GP or hospital to fill in a questionnaire. No dedicated medical team was formed to undertake health assessments. One doctor from the Darling Downs Public Health unit was given the task of collating the information from the 13 HEALTH numbers and local doctors. This was in addition to their normal work load. No referral system was set up to assist the local doctors.[iv]

On 11th and 12th October 2012, Dr Keith Adam, held a clinic in Tara as part of the promised Queensland Government investigation. The clinic was poorly advertised. A second clinic was promised but never took place. Dr Adam is from Medibank Health Solutions, a private healthcare company and is retained as a consultant by two large coal companies.[3]

By February 2013 no health report had been published, yet both the industry and politicians had repeatedly stated that Queensland Health had investigated and no health problem had been found. In a letter printed in The Sydney Morning Herald(19th January 2013), Rick Wilkinson, Chief Operating Officer Eastern Region, Australian Petroleum Production & Exploration Association Ltd (APPEA) claimed that Queensland Health had *"reported no pattern of illness consistent with effects from natural gas extraction."*[4]

[iv] Shortly after announcing the health investigation, the Queensland Government sacked 14,000 public servants including many from Queensland Health.

Given the events and circumstances outlined above, I reluctantly concluded that the Government had no real commitment to investigate public health complaints related to CSG development. As a general practitioner, I was concerned about the potential long-term damage being done to the health of the people living in the residential estates. I decided to carry out my own study to clarify whether or not the implication that only a "handful" of people perceived health impacts was true, and then to document these perceived health impacts.

This paper does not claim to be a comprehensive health assessment of the people living within the Queensland gas fields. It is a health survey based on the voluntary work of one person in conjunction with the residents. In the nine months of their investigation the Queensland Government had the opportunity, the time and the resources to do what is necessary: to set up a detailed research study including comprehensive history taking, full clinical examination, testing and long term follow up. That still remains to be done. A comprehensive study would effectively investigate exposure and symptoms. It could compare the symptoms of those living near gas wells with those not exposed, or it could investigate the individual exposures of those who complain of illness with those who appear well. It would, as an added benefit, pick up and provide opportunity to treat cases of unrelated illness which have fallen through the gaps in the health system.

This study has significant limitations as there will be bias in the way the study participants have been selected and also in the fact that they are being asked to recall past events without independent verification. It is the opinion of the author that a study of this type could not be blinded. Nevertheless it has succeeded in obtaining data on a greater number of people than the official government investigation has done and has confirmed the extensive clustering of serious health complaints in this region. In addition, the significance of neurotoxic symptoms being reported with such frequency, especially in children, remains an issue of great concern, and should be fully investigated.

METHOD

On nine days between 24th February and 16th March 2013, I surveyed the health of people within 35 households in the Tara residential estates and the Kogan/Montrose regions of the Western Downs in Queensland. In addition to that I conducted telephone interviews with families from three households who had left the area because they believed their health had been adversely affected by CSG. One family moved 80km away but remained within 4413 post code, one family moved to postcode 4305 and one family moved interstate to post code 3380.

These locations were chosen to survey as residents from these areas had previously contacted the Gasfields Community Support Group with health concerns they related to CSG exposure.

In the majority of cases I documented the residents' responses; in a few cases the respondents preferred to complete the paperwork themselves. Parents provided current health data on their children with input from older children and parents provided comparison data on their children's health prior to CSG.

The survey was in two parts. Part 1 documented the environmental details of each household including perceived impact on animals. Part 2 was an individual questionnaire regarding the health of each person within each household. The first page was age specific.

For children aged up to 5 years this involved answering affirmatively if the parent was concerned about any of 25 health issues. There was a question whether the parent believed the child's health had been adversely affected by CSG with the options on answers being "yes", "no" and "uncertain". There were free form questions on perceived health impacts and their experience seeking medical help.

As no baseline health studies had been carried out prior to coal seam gas development, in lieu of baseline studies, for people aged 6 to 82, the first page of their health questionnaire was designed to compare how their health was perceived to be in the past two years[v] whilst living in a gas development with their health in the two year period before they were exposed to the CSG industry. For before and after CSG, there were 30 questions, the answers to which were "never", "occasionally", "often" or "constantly".

[v] Or for a lesser period if they had moved to the area within that two year timeframe

For the purpose of the questionnaire the definitions were as follows:

Definition	Details of definition
Never	Never.
Occasionally	That it has happened ever (within the 2 years[v]), a few times, sporadic.
Often	Recurring, regular, frequent.
Constantly	At least twice a week.

TABLE 1 QUESTIONNAIRE DEFINITIONS

There was a question on diagnoses made prior to CSG development and conditions diagnosed since CSG development. One question related to whether the respondents believed their health had been adversely affected by CSG and there were open format questions on health impacts and medical care.

With the assistance of the Gasfields Community Support Group,[5] I visited some of the families who had previously stated that their health was impacted. In order to minimise bias, I endeavoured to visit and survey the near neighbours of impacted families. Of the 40 families I approached, only two declined to participate. Locked gates with "For Sale" signs proved to be more of an obstacle to participation. Families were willing to respond with the assurance of anonymity. Although identifying data such as names and addresses was collected, only postcode and/or survey number would be used in the pooled results.

FINDINGS

NUMBER SURVEYED

In total the health of 113 people from 38 households was documented.

There were 17 children between the ages of 0 and 5, 31 children between the ages of 6 and 18 and 65 adults between the ages of 19 and 82. This included just two people aged over 70 years. There were 56 males and 57 females.

ENVIRONMENTAL DATA

53 people lived within postcode 4421, 40 people lived within postcode 4413, 15 people lived within postcode 4406 and 3 people now lived in 4305 with two people in 3380.

Of the thirty eight households canvassed, 3 families lived in second dwellings on the acreage blocks so the environmental data was collected for 35 blocks

Of the 35 blocks 12 families had owned them for less than 5 years, 10 families for 6-9 years, 8 families from 10 to 19 years and 5 families for between 20 and 40 years.

The smallest residential block was 30 acres. 16 families lived on blocks of 30 or 40 acres. 8 families lived on blocks of between 50 and 100 acres. 7 families lived on blocks of between 110 and 250 acres and 4 families outside the residential estates lived on blocks of between 640 and 8000 acres.

15 households used solar as their main source of power, while 15 had mains electricity and 5 used a generator as the primary source. 9 households had a generator as back up while 4 had solar as their secondary source of power.

24 households used gas for cooking while 11 used electric cookers or cooktops. 21 used a woodstove or wood heater.

3 households used bottled water for drinking and cooking. The rest used rainwater collected from the roof into tanks for drinking, cooking and washing dishes. 5 households used settled dam water treated with alum for washing clothes. 3 families habitually washed their clothes in town. 3 households used treated dam water for bathing, the rest used rainwater. Dam water and rainwater was used in various combinations for vegetable gardens and domestic animals and in one case for watering the lawn. Only one person swam in their dam. Four families used dam water to flush the toilet. Several families did not use their dam at all. Some believed it had been contaminated by run off from road spraying of CSG flow back.

There was a bore on three properties. None were currently used. One of these bores had sustained 145 head of cattle throughout Queensland's long drought. However, that bore is now flammable.

Flea and tick prevention was used by 13 households but otherwise pesticides and herbicides were used very sparingly around the home or garden; two households used pyrethrin ant sand; three occasionally used Roundup; one had treated for termites; one used Graslan in the paddocks. Several households were proudly organic.

Only one household had purchased new or refinished furniture or carpets.

For one family the nearest well was at a distance of 5km. For everyone else the infrastructure was much closer. One family had a major gas development site 20 metres from their property. For 6 families the nearest well was between 500 and 800 metres; for 6 families the nearest well at approximately one kilometre; for 5 families the nearest well was 1.5km; for 13 families the nearest well was 2-3km away; for 3 families the nearest gas well was approximately 4km away.

Many families were aware of multiple infrastructure including wells, compressors stations, pumping stations, vents, and open CSG waste disposal ponds in various directions from their homes which were operated by different companies including QGC, Origin and Linc Energy. Many families were unsure what infrastructure they were in proximity to. 18 families were aware of non-agricultural odours through their property.[vi] The intensity, frequency and duration were variable and depended on wind direction. Most people noticed the problems were worse when the wind was coming from the north. 11 families were aware of unusual cracking of the soil on their property and 8 families had seen bubbling in puddles on their property after the rain while one man, though not ever noticing a problem on his own property, had watched bubbling in cracks in the bitumen road which was covered in 6 inches of water at the time.

HEALTH DATA

Note that a complete set of the data is available in Appendix B.

Of the 113 people surveyed 66 or 58% were certain their health was being impacted by CSG. (Figure 2)

26 people (23%) felt sure that their health had not been impacted and 21 people (19%) were uncertain.

Of the 113 people there were 95 individuals in the age 6-82 age cohort who answered the 'before' questionnaire with 96 individuals answering the 'after'. The reason for this was that one child had to all extents and purposes always lived in the gas field so had no prior health history. For this reason the data for before and after has been in each case documented in separate pie charts.

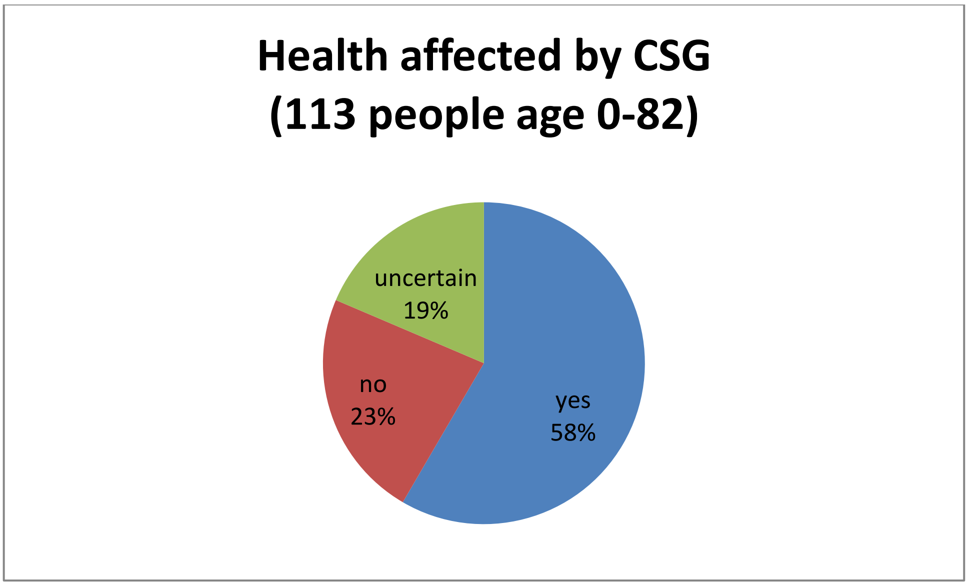

FIGURE 2 HEALTH AFFECTED BY CSG (113 PEOPLE AGE 0-82)

[vi] In August 2011, Queensland Country Life reported Linc Energy offered to purchase air-conditioners for some of the surrounding farmers' houses so long as the landholders were willing to sign a confidentiality agreement and not tell anyone about the matter.

Visual representation of the data in this format is striking and shows major changes in perception of wellbeing for large percentages of the people surveyed. Of particular concern is the type of symptoms experienced as they are not symptoms one would expect due to aging alone over a 2-5 year time frame.

Skin irritation was a good example of the change in symptoms with 17% reporting skin irritation before CSG and 72% complaining of skin irritation after CSG. (Figures 3 and 4) People reported symptoms of discomfort, sensitivity, itch and inflammation of their skin which, particularly in adults, was often in the absence of a visible rash.

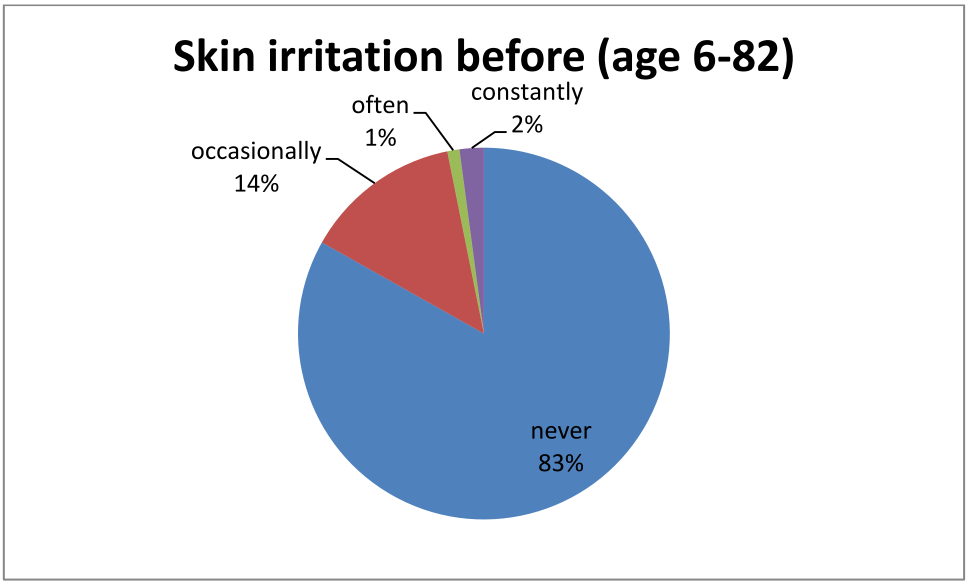

FIGURE 3 SKIN IRRITATION BEFORE CSG (AGE 6-82)

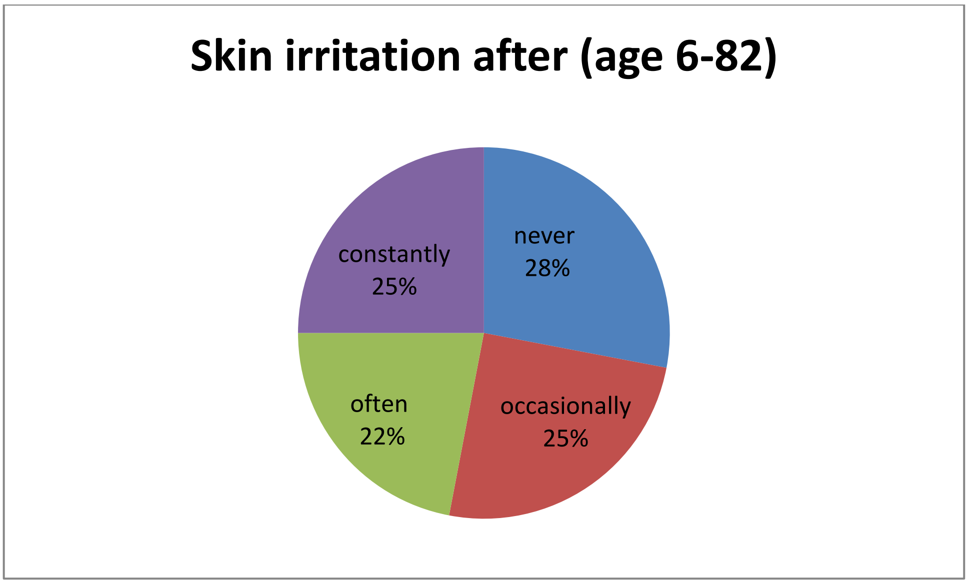

FIGURE 4 SKIN IRRITATION AFTER CSG (AGE 6-82)

Eye irritation was reported with similar frequency, with 7% reporting symptoms before and 60% after. (Figures 5 and 6)

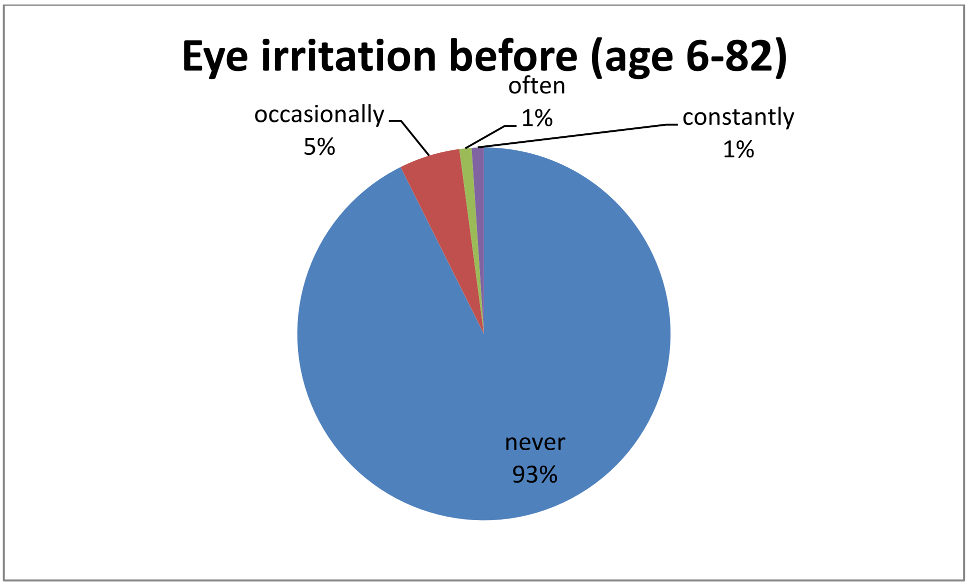

FIGURE 5 EYE IRRITATION BEFORE CSG (AGE 6-82)

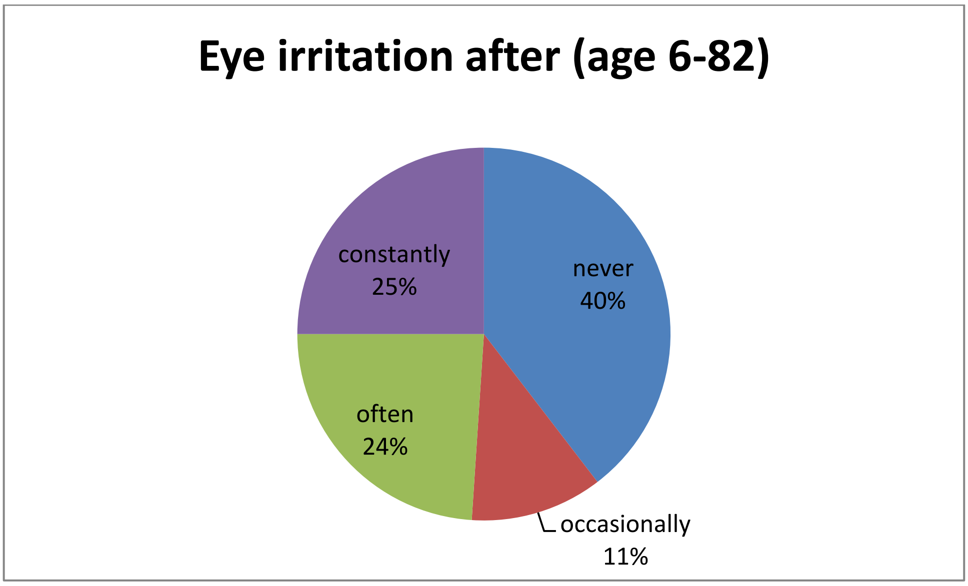

FIGURE 6 EYE IRRITATION AFTER CSG (AGE 6-82)

Likewise 7% reported trouble with spontaneous nose bleeds before CSG while 32% had spontaneous nose bleeds after. (Figures 7 and 8)

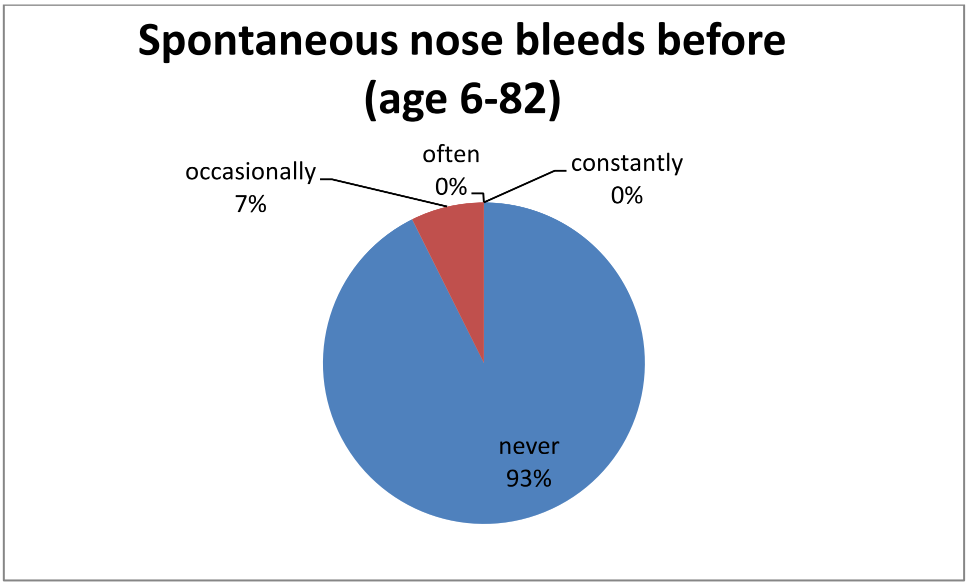

FIGURE 7 SPONTANEOUS NOSE BLEEDS BEFORE CSG (AGE 6-82)

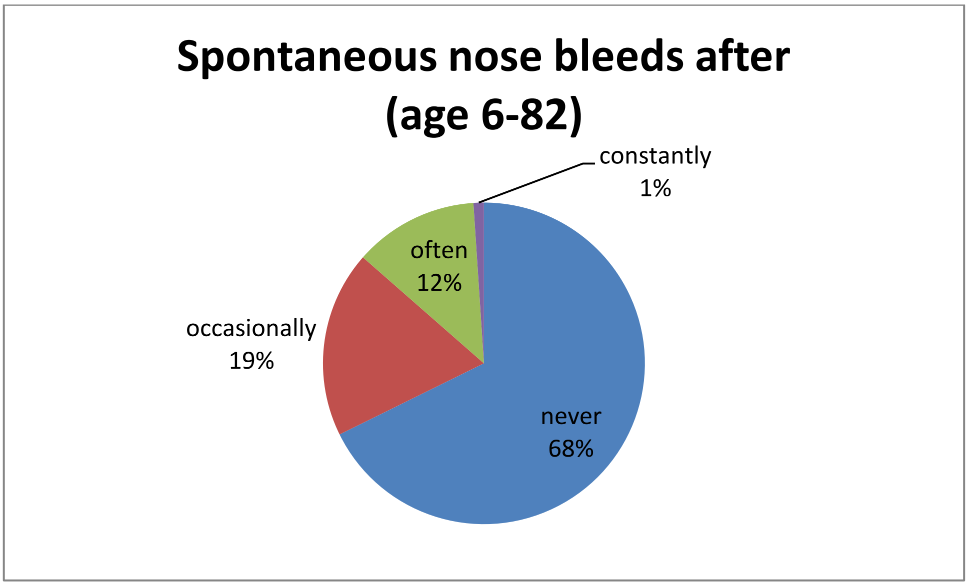

FIGURE 8 SPONTANEOUS NOSE BLEEDS AFTER CSG (AGE 6-82)

There was a marked increase in a range of symptoms which can be related to serious conditions such as neurotoxicity (damage to the nervous system), including weakness, severe fatigue, headaches, numbness and paraesthesia (abnormal sensations such as burning or tingling).

- 54% reported mild headaches prior to CSG while 87% had mild headaches after; (Appendix B)
- 23% reported having ever had a severe headache before CSG, while 55% had severe headaches after (38 % often or constantly); (Appendix B)
- 13% reported suffering from severe fatigue before while 64% suffered from severe fatigue after; (Appendix B)
- 7% reported suffering from weakness before while 51% were symptomatic after. (Figures 9 and 10)
- Depression and anxiety, difficulty concentrating and insomnia showed similar reported increases. (Appendix B)

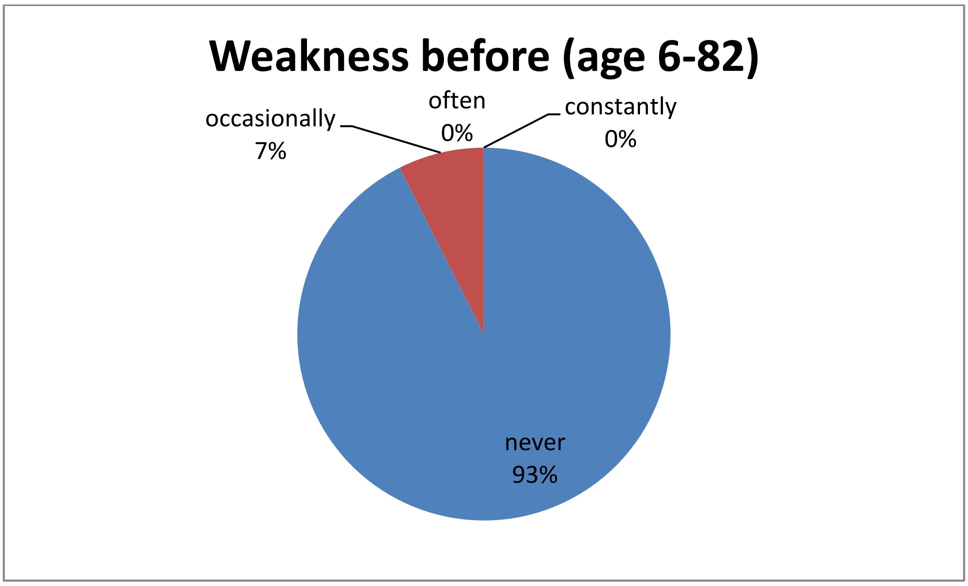

FIGURE 9 WEAKNESS BEFORE CSG (AGE 6-82)

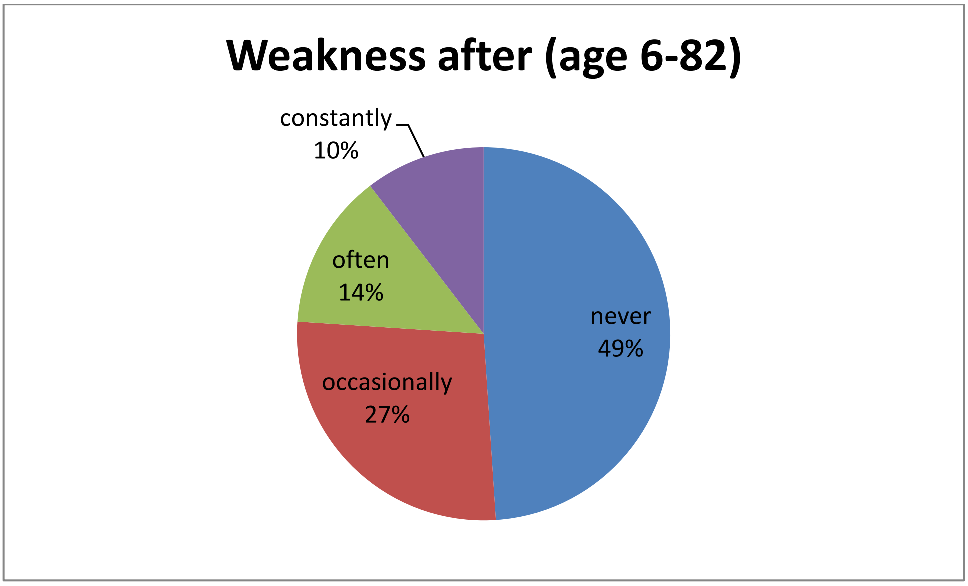

FIGURE 10 WEAKNESS AFTER CSG(AGE 6-82)

Reported symptoms of tingling, numbness, and pins and needles increased from 8% prior to CSG to 42% after. (Figures 11 and 12)

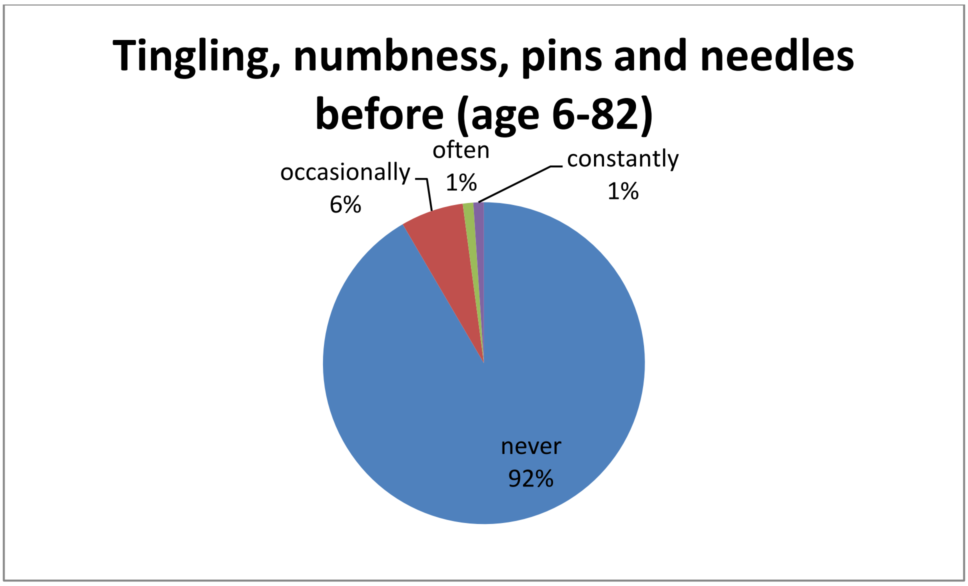

FIGURE 11 TINGLING, NUMBNESS, PINS AND NEEDLES BEFORE CSG (AGE 6-82)

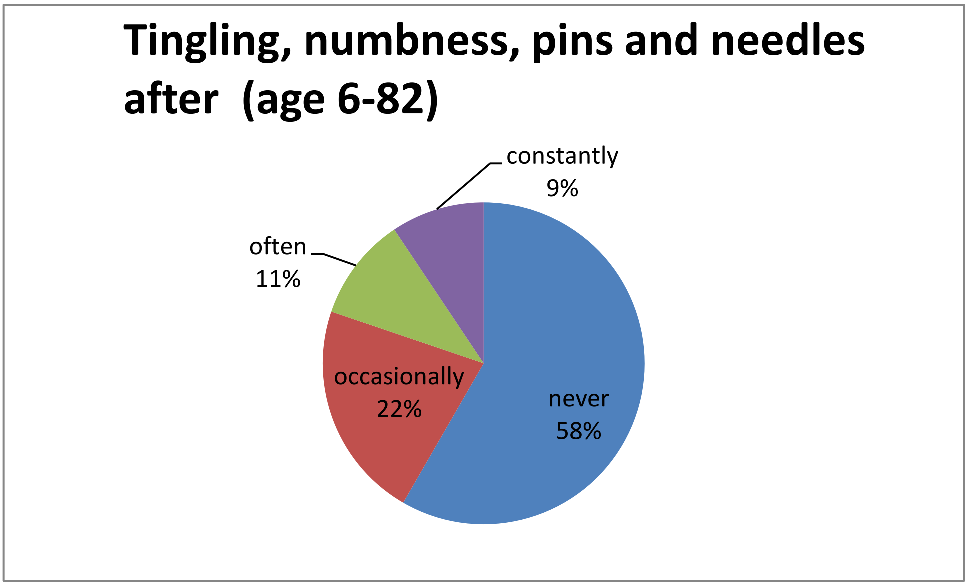

FIGURE 12 TINGLING, NUMBNESS, PINS AND NEEDLES AFTER CSG (AGE 6-82)

In order to determine if the symptoms were age related, the data was reanalysed for the age 6-18 age group. There were 31 children in this group (Appendix B). Since the results were similar for chest discomfort, chest tightness and difficulty breathing, only chest tightness was displayed in a pie chart. The results are striking.

After CSG

- 19 out of 31children or 61% had spontaneous nose bleeds reported;

- 28 out of 31 children had mild headaches, 23% constantly;
- 17 out of 31 children had severe headaches, 4 of them or 13% constantly;
- 24 out of 31 children had skin irritation- 15 (almost 50%) often or constantly throughout the past two years;
- 10 out 31 children age 6-18(over 30%)experienced paraesthesia
- 8 out of 31 (26%) had severe chest pain;
- It was reported that children had increased rates of cough, chest tightness, difficulty sleeping, nausea, rashes, difficulty concentrating and muscle pains and spasms.

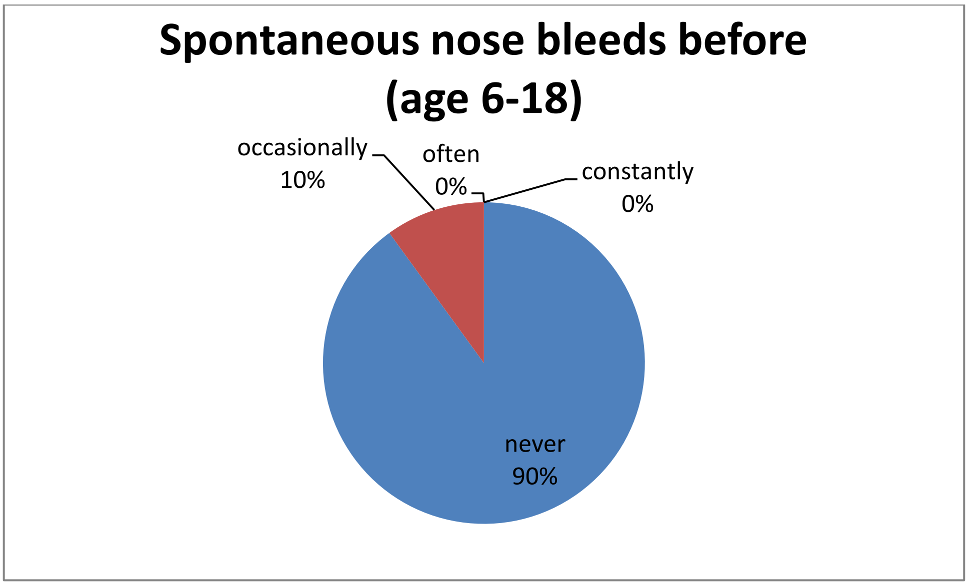

FIGURE 13 SPONTANEOUS NOSE BLEEDS BEFORE CSG (AGE 6-18)

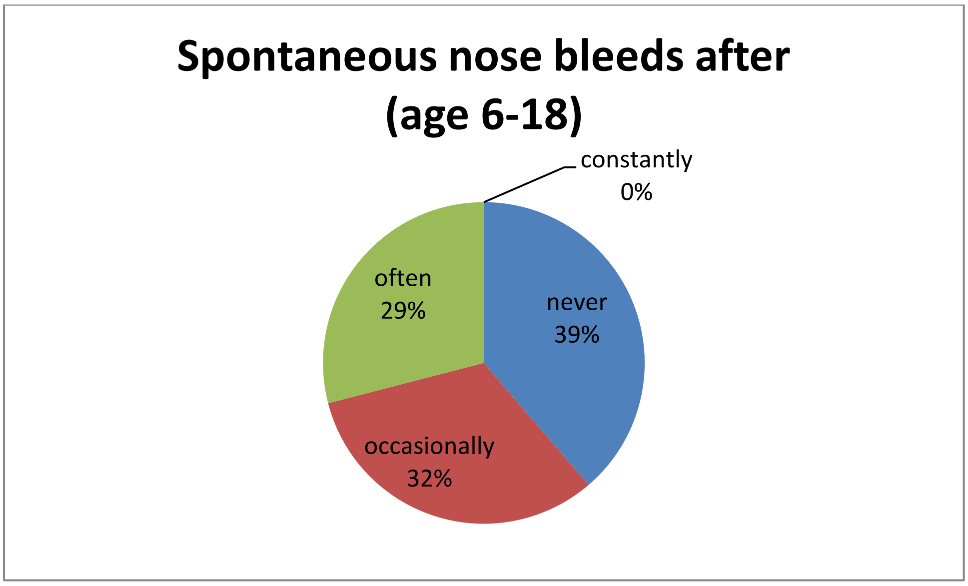

FIGURE 14 SPONTANEOUS NOSE BLEEDS AFTER CSG (AGE 6-18)

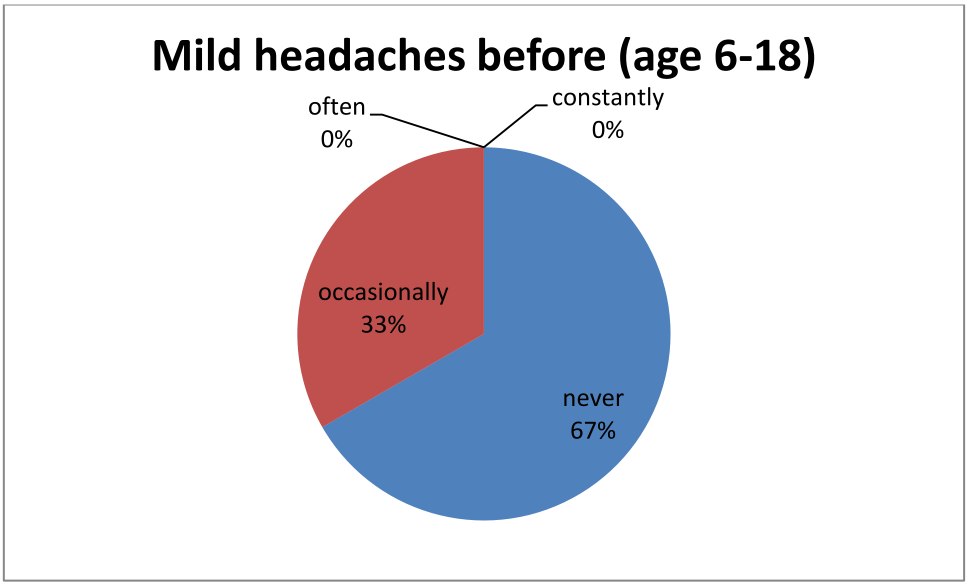

FIGURE 15 MILD HEADACHES BEFORE CSG (AGE 6-18)

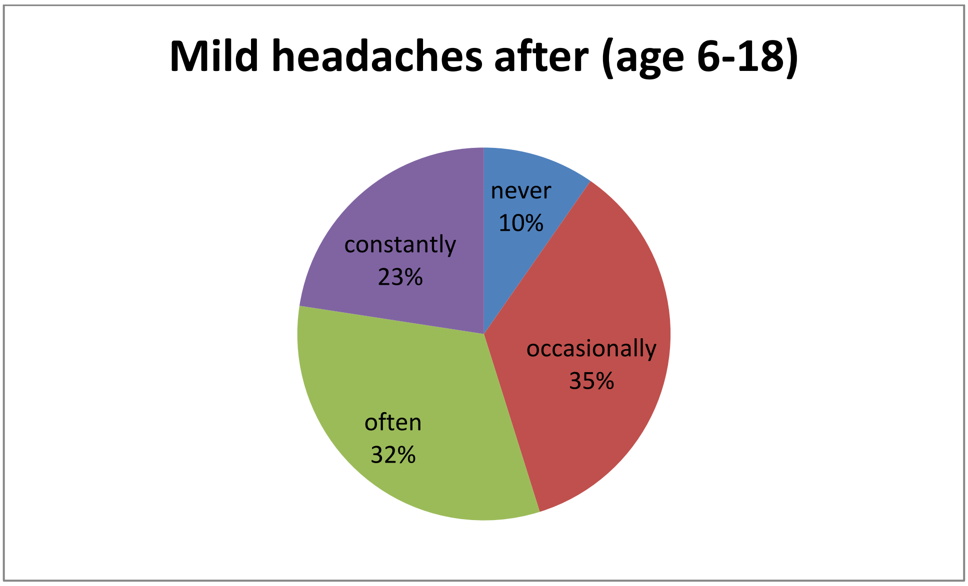

FIGURE 16 MILD HEADACHES AFTER CSG (AGE 6-18)

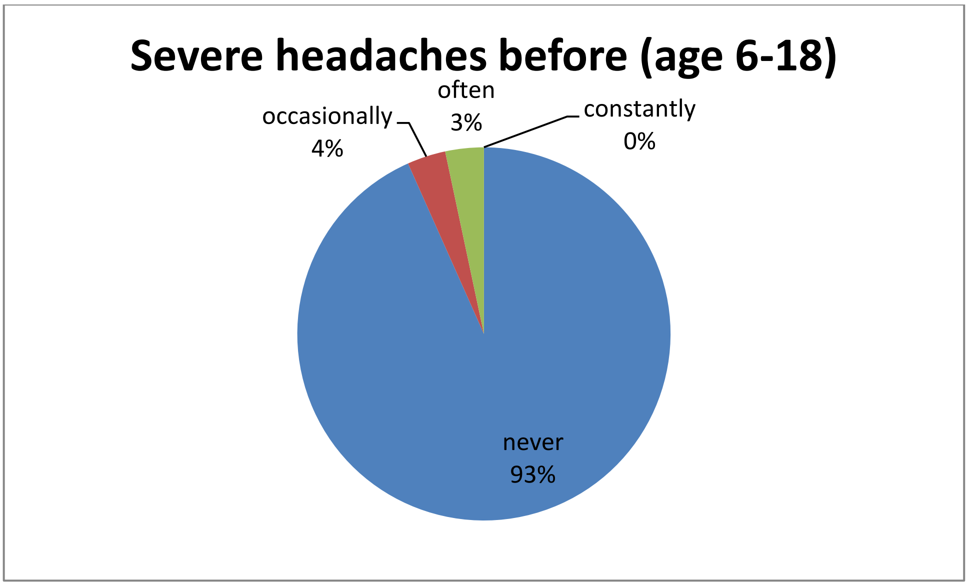

FIGURE 17 SEVERE HEADACHES BEFORE CSG (AGE 6-18)

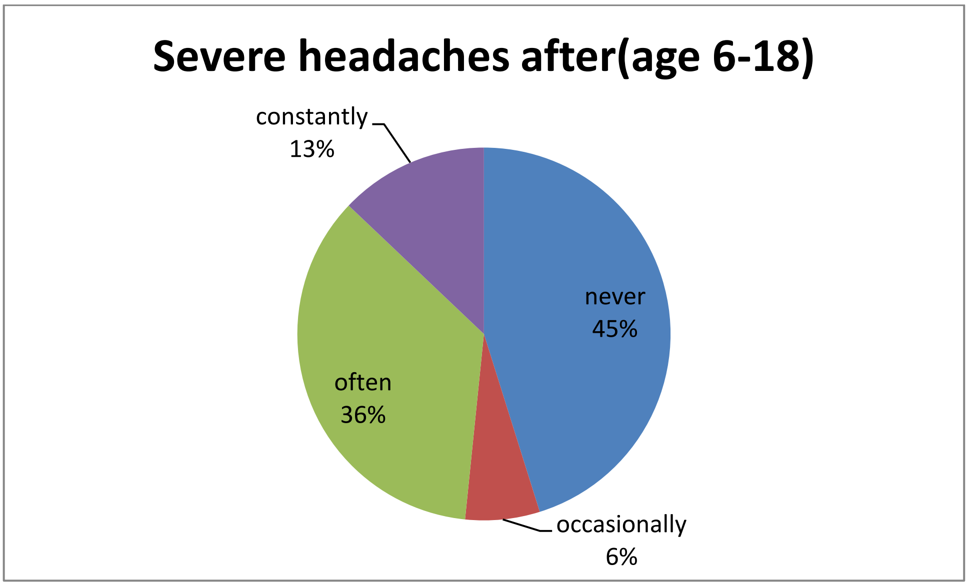

FIGURE 18 SEVERE HEADACHES AFTER CSG (AGE 6-18)

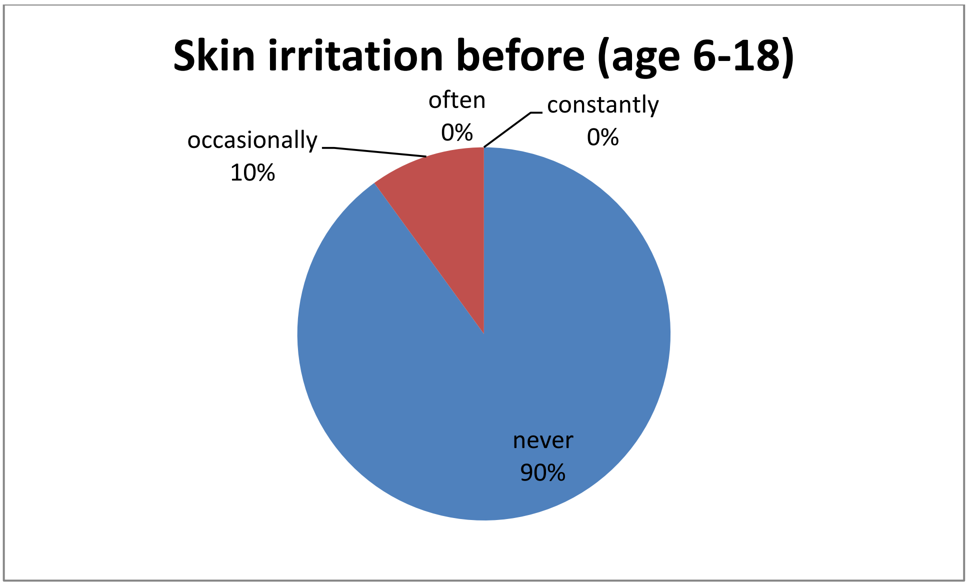

FIGURE 19 SKIN IRRITATION BEFORE CSG (AGE 6-18)

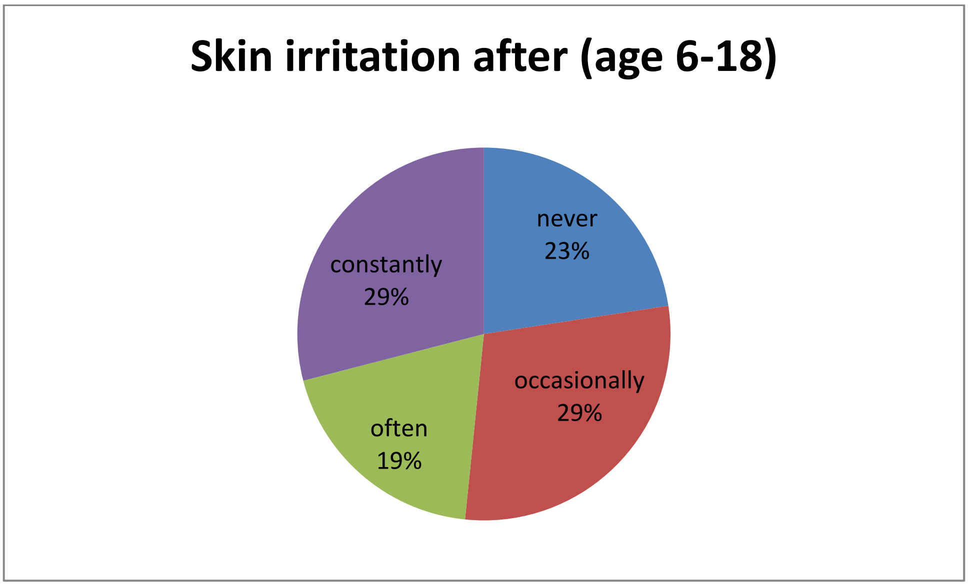

FIGURE 20 SKIN IRRITATION AFTER CSG (AGE 6-18)

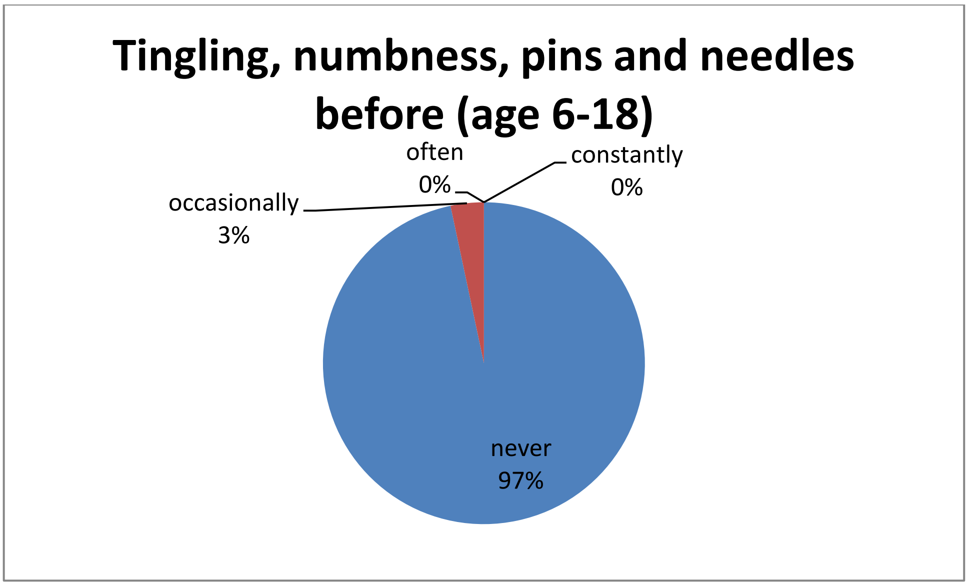

FIGURE 21 TINGLING, NUMBNESS, PINS AND NEEDLES BEFORE CSG (AGE 6-18)

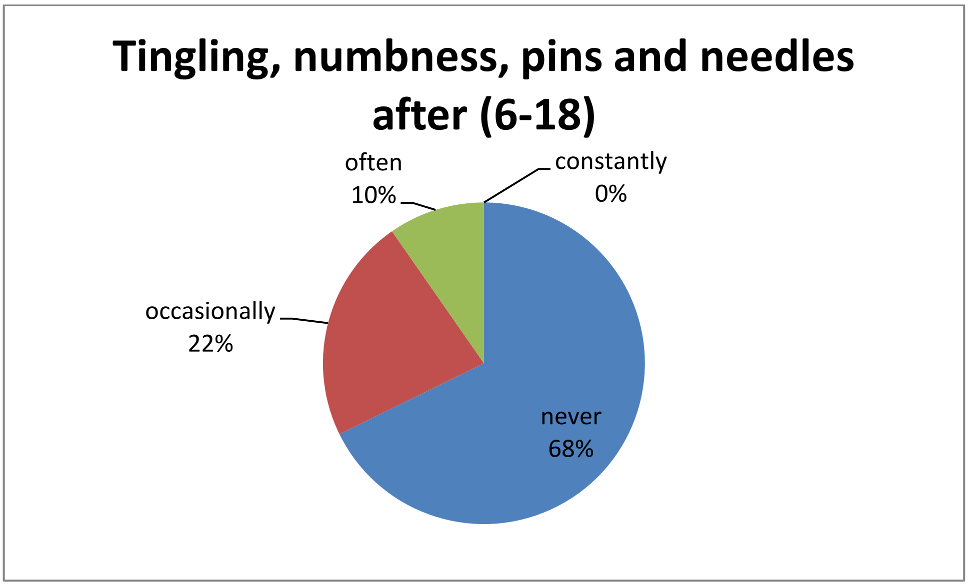

FIGURE 22 TINGLING, NUMBNESS, PINS AND NEEDLES AFTER CSG (AGE 6-18)

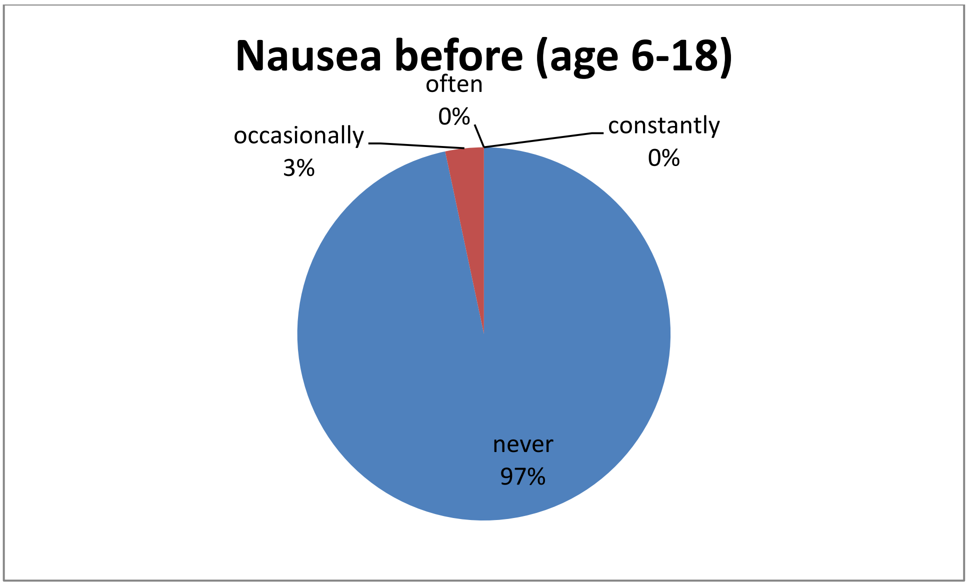

FIGURE 23 NAUSEA BEFORE CSG (AGE 6-18)

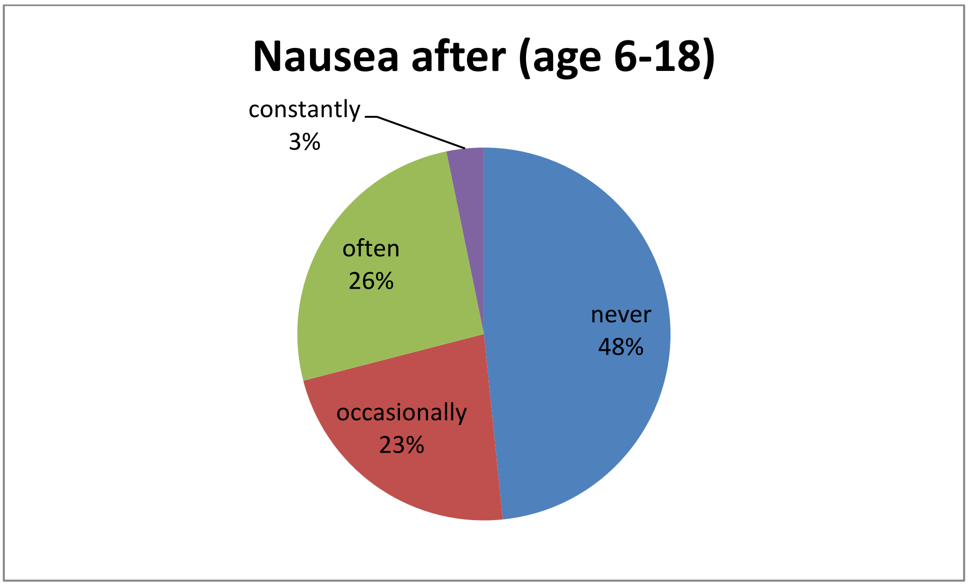

FIGURE 24 NAUSEA AFTER CSG (AGE 6-18)

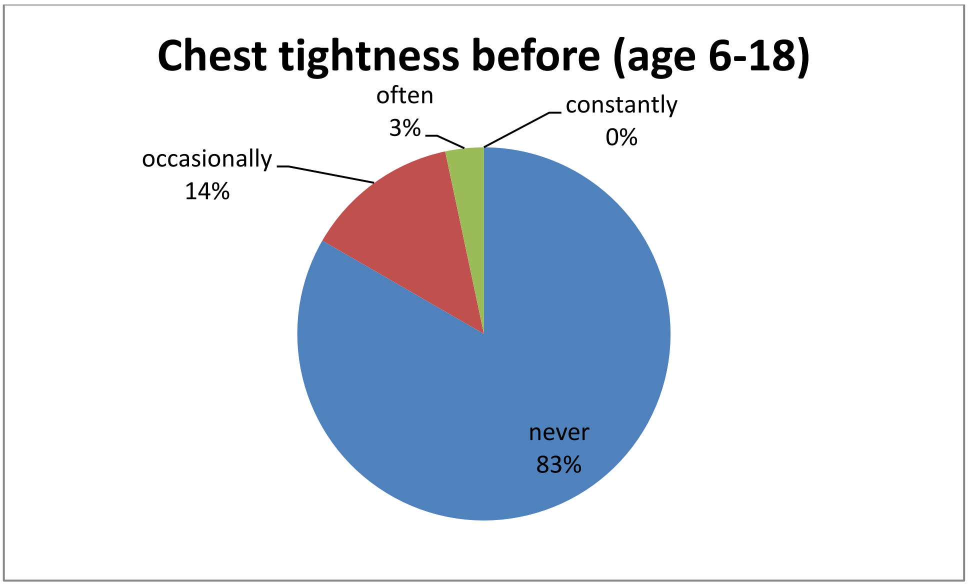

FIGURE 25 CHEST TIGHTNESS BEFORE CSG (AGE 6-18)

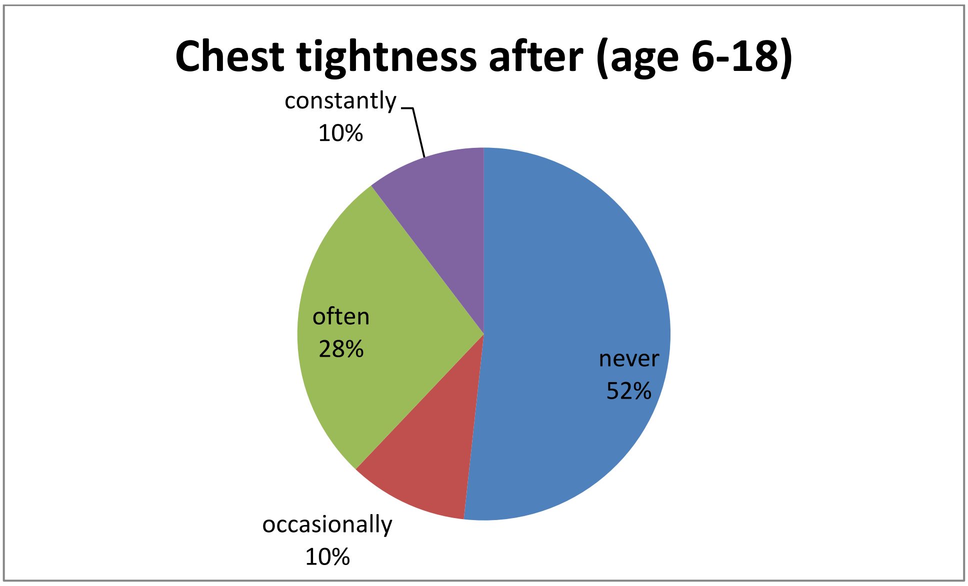

FIGURE 26 CHEST TIGHTNESS AFTER CSG (AGE 6-18)

PARENTAL CONCERNS

There were 17 children in the age group 0-5. Parental concerns for their children included rashes (11), eye irritation (11), and cough (5).

Significant concerns reported in this age group were:

- twitching and unusual movements (6);
- poor colour/blueness of mouth or limbs (6);
- blood from the nose (9);
- headaches (8);
- tingling/numbness/ pins and needles (5).

Of the 13 children who were walking, 5 were reported to have demonstrated unusual clumsiness or unsteadiness.

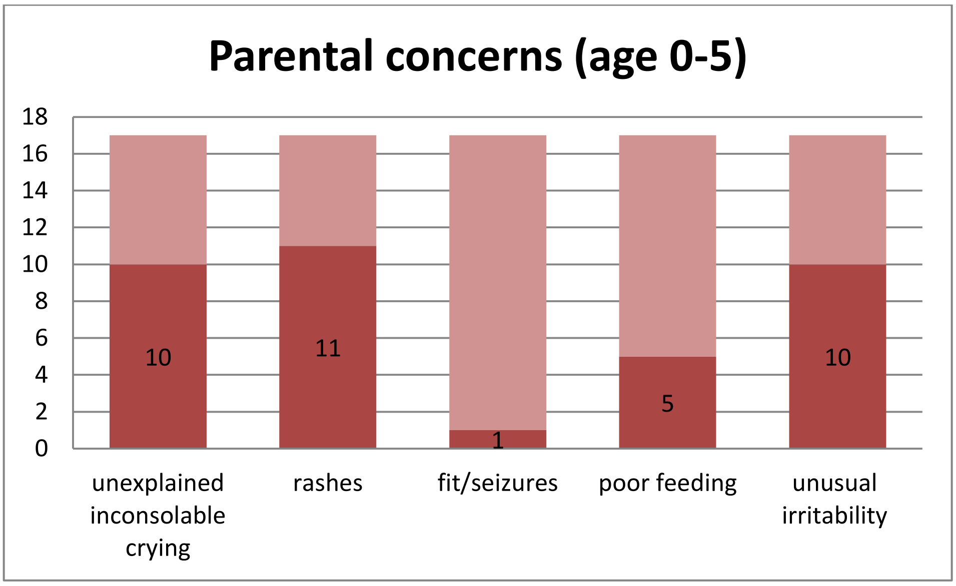

FIGURE 27 PARENTAL CONCERNS (AGE 0-5)

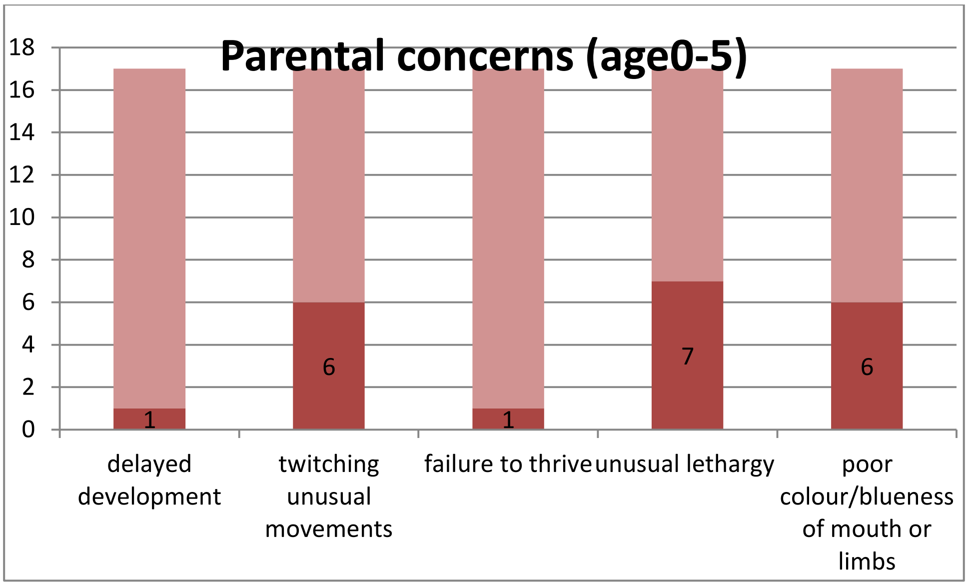

FIGURE 28 PARENTAL CONCERNS (AGE 0-5)

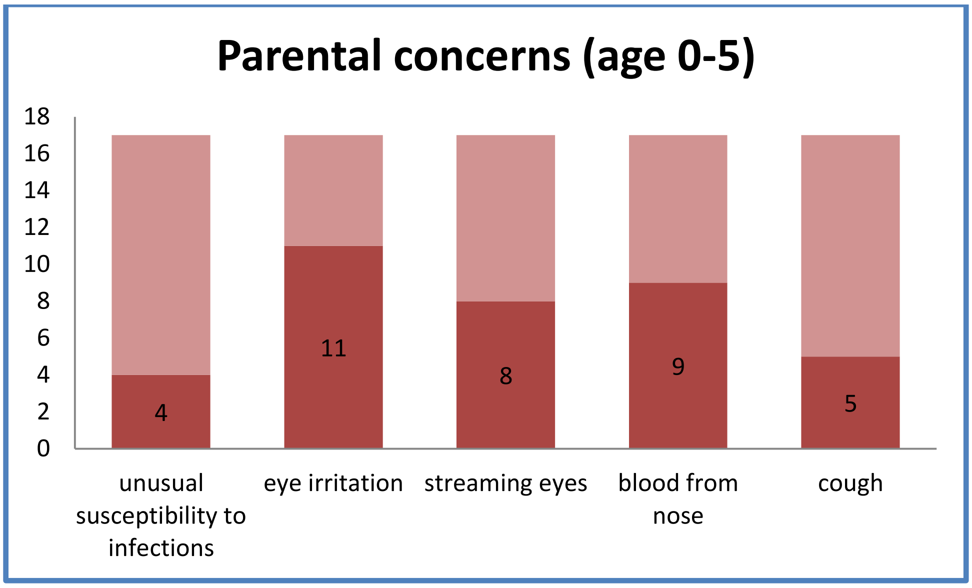

FIGURE 29 PARENTAL CONCERNS (AGE 0-5)

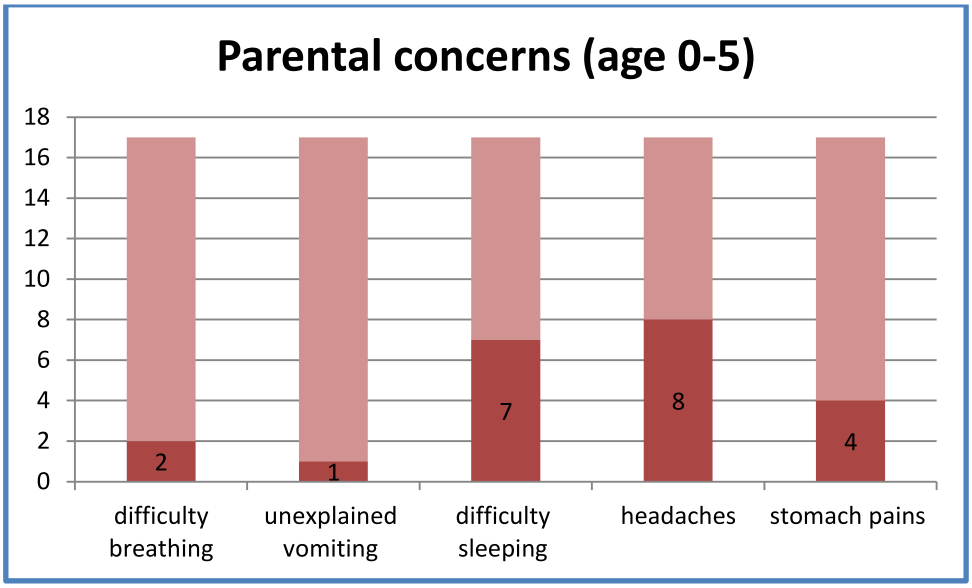

FIGURE 30 PARENTAL CONCERNS (AGE 0-5)

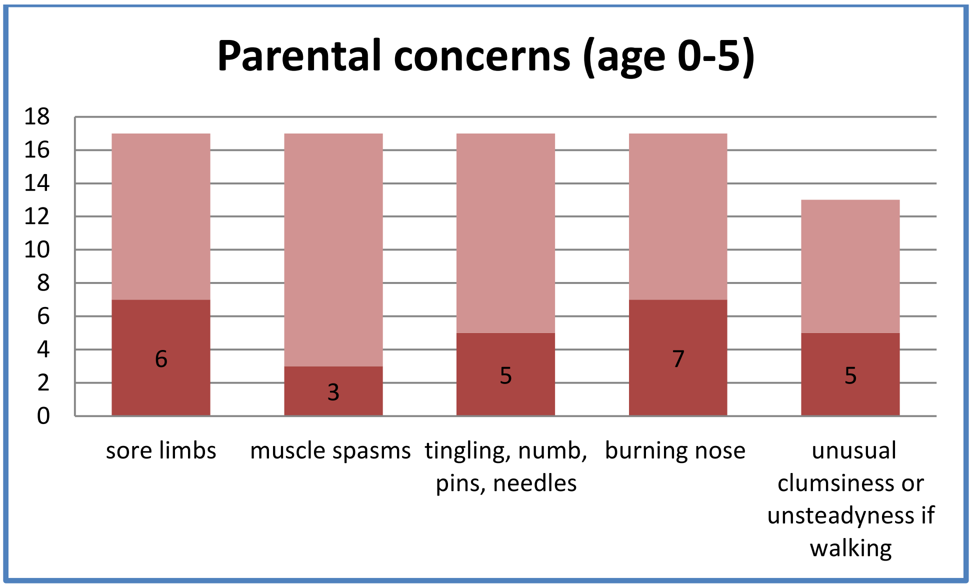

FIGURE 31 PARENTAL CONCERNS (AGE 0-5)

RESIDENTS' COMMENTS AND FEEDBACK

Residents' comments on health impacts were enlightening. Parents particularly noted their children coming in from playing outside with nose bleeds. Often they had linked increased frequency of these occurrences with wind direction and some had stopped their children playing outside at these times. Some adolescents had had daily nose bleeds for three months at a time. These rural children now deliberately avoided going outdoors when possible. Adults who had lived in the bush all their life now found their lives restricted to indoors.

Children were noted to be constantly rubbing their fingers. Children complained of ants in their hands and one infant reportedly screams and dips his fingers in water in the middle of the night. Children were reported to be waking at night in distress wanting their mums to rub their limbs. The only child who has been sent for evaluation by a paediatrician for this complaint was reportedly told she was attention seeking. Children were reported to be waking out of their sleep with headaches.

For adults and children alike, eye irritation and skin irritation, particularly when outside, were said to be constant background complaints, with severe exacerbations linked to odour events. So extreme was the discomfort for some people, they described that they felt they could rip their skin. Some said that after the odours came through, their skin felt like it had been washed by acid and their skin peeled in the shower.

Infants, children and adults alike suffered from headaches. Some had been so intense that they had been investigated with CT scans and lumbar puncture.

OTHER HEALTH AND WELL-BEING COMPLAINTS

Extreme fatigue, difficulty focusing and difficulty concentrating were new and debilitating symptoms for many residents. Symptoms were worse when odours came through. Some people could identify distinct individual odours at different times, variously described as:" rotten eggs, sickly sweet, like pine tarsal, acetone, creosote, after burn from cigarette lighter." Many people noted the association between their symptoms, wind direction and the location of the CSG waste water/evaporation ponds. Some people commented on the link between road spraying and their symptoms.

Children and adults alike complained recurrently of a metallic taste which made them nauseous and anorexic. Undiagnosed cough, repeated diagnosis of 'flu', pneumonia, pleurisy and exacerbation of asthma were recurrent themes. Children were missing a lot of school. Sleep disturbance was endemic within the families surveyed. Many people related this directly to the noise associated with CSG activities: trucks moving, reversing, beeping, the noise and vibration from drilling, fracking and seismic testing. Some people were very clear that their sleep was disturbed by noise and vibration from the compressor station, at distances up to 15km away. Many other people's sleep was disturbed by the constant strain of living with, and dealing with, the impact of CSG on their daily lives. Many expressed helplessness and hopelessness in the face of their children's ill health and their inability to help and protect them. Some had the capacity to move away and did. Most found themselves trapped.

RESIDENTS' PERCEPTION OF HEALTH CARE

Residents who felt their health was not impacted in general had few comments on health care. A couple were happy with medical services in general. Several children were seen by paediatricians in Brisbane, and the families were happy with treatment there.

Residents who felt their health had been impacted had some disturbing comments on their experience of health care. Their experiences were based on presentations to different hospitals and medical practices in the local area including Chinchilla, Dalby, Tara and the Toowoomba base hospital. At one clinic a seriously ill, febrile infant was reportedly left unseen for 1½ hours while a stream of energy workers came and went. When eventually seen, this child was transferred as an emergency first to Toowoomba and then to Brisbane.

Residents reported being turned away from medical facilities without treatment with the triage nurse making the decision whether they would be seen by a doctor or not. People commented that after a one hour trip to see the doctor, and a four hour wait they were given a survey to fill in and turned away. For one family whose children presented with rashes and cough, the triage nurse made the unusual diagnosis of "flu" and turned them away without treatment.

A patient attended hospital with chest pains to be reportedly told by the nurse: "I'm not bringing the doctor in for this." At midnight, on the advice of the medical advisor on the 13 HEALTH line, a person with severe chest pain reportedly phoned triage at one of the larger hospitals and was told to take two panadol and go to bed.

People had the definite perception that if they questioned whether their symptoms were related to CSG they were treated differently and were shunned. A referral to the mental health service ended months later, without ever being seen, with a phone dismissal of the possibility of depression and the statement they were just frustrated with CSG.

When actually seen by the doctors the frequent impression gained was that they did not want to know. Comments included : *"just fobbed off"*, *"disappointing"*, *"unsatisfactory"*, *"not being taken seriously by health authorities"*, *"no idea why coughing"*, *"recurrent rashes, told dermatitis/allergy, asked about the effect of gas, told 'just old age'"*, *"undiagnosed"*, *" treated poorly, didn't help with anything, waited a long time for them to tell him to go home"*, *" given eye drops"*, *"given steroids"*, *" made him feel like a hypochondriac"*, *"told allergic reaction"*, *"given antidepressants"*, *" told didn't know what it was"*, *"no tests"*, *" told all in head- worrying about nothing"*, *"constant flu"* *"chest pains unexplained"*, *"referred months ago-no appointment"*, *"doctor laughed at her when she said she had a metallic taste in her mouth"*, *"no diagnosis or explanation"*, *"demoralised by lack of treatment by Queensland health"* and *"bunch of idiots."*

A paediatrician in Toowoomba told the parents that we *"are not here to discuss the gas."* One doctor, whilst empathetic, said they couldn't get involved as they worked for Queensland Health saying *"got to stay out of this."*

WORKERS SURVEYED

Of the 113 people surveyed, 4 worked in the CSG industry. Two of these were involved in infrastructure construction and although both had ongoing skin irritation, neither believed their health was impacted. One person, after 4 months employment in a CSG facility, began to develop severe symptoms in their hands and feet. After biopsy they were eventually diagnosed with neuropathy (nerve damage) and can no longer work. The fourth worker also has a symptomatic neuropathy which has been, without tests, diagnosed as carpal tunnel. They also suffer from severe fatigue, headaches and nausea.

DISCUSSION

This small survey is not a comprehensive epidemiological study. However it does refute the assertion that *"just a handful of people are complaining that their health is affected by CSG."* Furthermore, the character and frequency of specific health complaints, particularly relating to potential neurotoxicity in both children and adults are concerning.

Almost all the 31 children aged 6-18 were reported to suffer from headaches to some degree, but in 17 of these children the headaches were severe and for four children constant (i.e. occurring at least twice a week). Approximately a third of the all the 48 children to age 18 (15/48) were reported to experience paraesthesia. Regardless of any potential recall bias of their pre-existing health status these numbers and the significance of these symptoms stand out as a matter of serious concern. Add to that reports of spontaneous nose bleeds (31 out of 96 people age 6-82 (32%)) severe fatigue (61 out of 96 people (64%), difficulty concentrating (59 out of 96 people (61%), eye irritation 20 out of 31children (64%) and skin irritation 69 out of 96 people (72%) and a pattern of ill health emerges which is undoubtedly abnormal in comparison to my suburban general practice. Parents of 6 of the 17 children, aged 5 and under, were concerned about twitching or unusual movements, and parents of 5 of the 13 children who were walking were concerned about their clumsiness or unsteadiness on their feet.

Considering that the rural residential estates near Tara is the most densely settled area in Australia to have seen intensive CSG development, the effect of any health impacts there should be taken seriously and investigated comprehensively.

LICENCES, HEALTH AND THE PRECAUTIONARY PRINCIPLE

Queensland continues to issue permits for rapid CSG expansion. Approximately 40,000 coal seam gas wells are planned across Queensland. In addition to that there are permits for shale gas and underground gasification. More than 80% of Queensland is under exploration licences. This could translate to a public health disaster.

The initial licences were issued in a cloud of controversy with compelling evidence that appropriate checks and balances to vet environmental safety were not undertaken. The consequences to public health were never part of the assessment at the time of issuing the initial licences. Health impacts are still not part of the assessment for the permits which have been issued since the initial licences. The precautionary principle was ignored: *"The precautionary principle asserts that the burden of proof for potentially harmful actions by industry or government rests on the assurance of safety and that when there are threats of serious damage, scientific uncertainty must be resolved in favor of prevention."* [6]

QUEENSLAND GOVERNMENT'S RESPONSE TO REPORTS OF ILL HEALTH

Shortly after the data for this report had been collected, the Queensland Government released the health report it had commissioned nine months earlier. Remarkably, the health minister Lawrence Springborg concluded that there was no evidence of health effects related to CSG.[7]

However the Queensland government report states:

"In summary the most that can be drawn from the DDPHU report is that it provides some limited clinical evidence that might associate an unknown proportion of some of the residents' symptoms to transient exposures to airborne contaminants arising from CSG activities."

As their report is based on minimal industry sampling and very limited clinical investigation this finding is important.

Following the publication of the Queensland Government's health report and Lawrence Springborg's assertion that CSG workers have had no health problems, a person previously employed on CSG drilling rigs in a different area of Queensland was so disgusted that they contacted the Gasfields Support Group to relate their story. That data is not included in the numbers for this study. This worker's ill health included nosebleeds, spasms of the hands and extreme difficulty breathing, making it impossible to continue work. Their comment was: *"They wiped their hands of me."*

CRITIQUE OF THE QLD GOVERNMENT REPORT

The Queensland Government report appears to be an exercise in minimisation and misrepresentation. The report is based on three sources of clinical data:

- calls to a 13 HEALTH number
- presentation to doctors and hospitals in Tara, Chinchilla, Dalby and Miles and
- two clinics attended by their expert in October 2012**.**

FAILURE OF ADEQUATE HEALTH SYMPTOM SURVEILLANCE AND DATA COLLECTION

The report states: *"A range of information available to the Department of Health up to January 2013 was used for the assessment."* The decision then, to exclude all presentations to doctors and hospitals from 13th November 2012 onwards from the data is perplexing. It is apparent however, that if the November/December time frame had been included it would have been difficult for the author of the government report to state:

"It is worthwhile noting that the formal symptom reporting has occurred almost exclusively during the winter months (July) when the use of wood heaters and open fires could be expected to peak."

Feedback from the residents indicates that the time frame November through December coincided with a major peak in reports of illness amongst the residents and multiple emergency presentations. It was directly as a result of that peak in severe symptoms that the urine of a three year old child was tested. Testing revealed extremely high levels of hippuric acid, the major metabolite of toluene, in his urine. As soon as she was aware of the result, the mother of this child immediately contacted her local Queensland Health doctor with the contents of this report.

Toluene metabolites found at high levels in a child in a non-occupational context is worrying, taking into account the short half-life i.e. toluene is quickly metabolised. This should have prompted investigation by the health department as a matter of urgency. Toluene is a known neurotoxin, an irritant and a suspected reproductive toxin that can be absorbed via inhalation.[8] It is known to be associated with coal seam gas[9] and has been found repeatedly in air samples in the residential estates.

No action was taken by the health department.

MINIMISATION OF RESIDENTS' HEALTH CONCERNS

The Queensland Government report attempts to normalise the residents' health complaints by citing various studies:

"...54% of school children age for to 18 years were reported by themselves or their parents as currently having at least one of the following skin conditions, such as acne/pimples, eczema/ dermatitis, tinea/ringworm, and warts/papilloma."

RASH, ADOLESCENT
PHOTO COURTESY OF LOCAL RESIDENT

There can be no ambiguity; the children in this study were not complaining of pimples, warts, papillomas or fungal infections; they are complaining of rashes which improve or disappear when they are removed from the gas fields. The government's defined health expert reports he saw just one rash. He was unable to offer a diagnosis. One wonders why it was not referred for further investigation.

RASH ADULT AFTER ROAD SPRAYING
PHOTO COURTESY OF LOCAL RESIDENT

RASH CHILD
PHOTO COURTESY OF LOCAL RESIDENT

The image above left shows a rash which appeared on the leg of an adult visitor to the estate after road spraying. This was diagnosed as hives.

The report cites 34% of residents living beside a chemical waste site at Kingston in 1990 as complaining of eye irritation as though this were an acceptable benchmark against which the complaints of the people of Tara can be measured.

REPORT BY CONTRACTED MEDICAL CONSULTANT

The Queensland Government report states that Dr Keith Adam was commissioned by the Department of Health to provide an independent expert opinion on the health complaints of residents in the Tara area with particular regard for the potential for the complaints to be linked to CSG activities.

The report states:

"Dr Adams commented that his review of peer-reviewed literature in regard to occupational exposure to CSG did not identify evidence of unique or substantial harm to employees in the industry. This is highly relevant as potential exposure among workers in the industry itself could be expected to be significantly higher than in a community setting among residents located up to many kilometres from CSG sites."

There is not a single reference in Dr Adam's report to any study, peer reviewed or otherwise, confirming lack of harm to CSG workers.

With reference to his role as the independent expert opinion on the potential for the health complaints to be linked to CSG activities, there are some specific comments made by Dr Adam which caused me particular concern. Firstly:

"Once a well has been drilled it becomes the only conduit for gas and water to reach the surface. The two products are separated below ground, with water being transferred to centralised collection and treatment points, and the gas being piped to processing facilities where it is dried compressed and fed into commercial pipelines."

These comments go to the heart of the underlying question: namely, is there a pathway, or are there pathways by which mixtures of volatile organic compounds (VOCs), heavy metals, radioactive materials and other chemicals associated with unconventional gas extraction can find their way on to the skin, up the noses, into the lungs and the blood stream of people who are living in close association with gas development? After all, if there were no possible pathway there could be no associated illness.

Not only is the well, after having been drilled, not the only conduit for gas to reach the surface, the Queensland Government itself recognised this and has documented the frequency of methane leaking from CSG wells in this very area. Of the 58 gas wells tested at the Queensland Gas Company(QGC) Kenya gas fields of Lauren, Codie and Kate in 2010, 26 wells (or 45%) were already leaking.[10]

In addition, gas migration from CSG wells is currently being investigated by scientists at Southern Cross University.[11] This research is in the public domain and indicates that gas migration from CSG wells is indeed occurring.

Of interest is their comment on one of the postulated mechanisms:

"We suspect that depressurisation (fracking, groundwater pumping) of the coal seams during gas extraction changes the soil structure (i.e., cracks, fissures) that enhance the release of greenhouse gases such as methane and carbon dioxide."

Regarding gas migration into water sources, there have been several reports in both the print and electronic media of gas bubbling up in the Condamine River. Currently the Queensland Government are carrying out an investigation[12] and stated in January 2013 following a preliminary report:

"While the results of this report don't provide definite evidence of the source or cause of the gas seeps, we are taking a long-term approach to find science-based answers to this phenomenon."

A further point of concern is Dr Adam's claim that the gas and water are separated below ground. This claim bears little scrutiny. It is the intrinsic fact that there is water in the gas and gas in the water that causes so many technical problems for the industry as discussed by Peter Lather writing in Gas Today, November 2011:[13]

"Challenges unique to CSG gathering systems include dealing with significant volumes of CSG water and its associated treatment. The presence of large volumes of water creates problems in the gathering system design, as there is water in the gas and gas in the water, even after the process of separation. In order to combat this low point, drains need to be designed to siphon the water out of the gas, and high-point vents need to be designed to extract the gas from the water.", "Working out where to install vents and low-point drains can be a bit of a dark art. For example, a good location to place one of these low-point drains is at the lowest point of a pipeline, which is often in the middle of a creek or stream …"

The Queensland Government also disagrees with Dr Adam. The Queensland Government website states:[14]

"*When CSG comes to the surface, water in the gas is separated".*

It is the fact that the methane must be separated not only from water but from its associated toxins and be "cleaned" before being shipped to markets overseas that provide many of the pathways for exposure of the local residents to volatile organic and other compounds. These processes include dehydration, compression and pumping, deliberate venting and flaring of wells and venting from high and low point valves scattered throughout the estates. Evaporation of volatile organic compounds from the giant CSG waste water ponds along with road spraying of CSG waste water provide yet more pathways for exposure.

PIPELINE VENT LOCATED INSIDE THE TARA RESIDENTIAL ESTATES
PHOTO COURTESY OF LOCAL RESIDENT

After confirming that benzene has in fact been found on testing in the residential estates, Dr Adam goes on to say:

"Benzene is not a normal constituent of coal seam gas, and so its source is uncertain."

This statement is directly contradicted by the Queensland Government Department of Environment and Heritage Protection website:[15] *"The BTEX[vii] compounds are found naturally in crude oil, coal and gas deposits and therefore they can be naturally present at low concentrations in groundwater near these deposits."*

In addition, The Sydney Morning Herald reported on August 28th 2011 that *"Benzene, toluene and xylene were discovered during routine tests of 14 bores used to monitor the company's* [Arrow] *coal seam gas (CSG) dams at the Tipton West and Daandine gas fields near Dalby*."[16] This was a year after Benzene had been outlawed as a fracking fluid in Queensland.

Dr Adam does note that the limits of detection by the analytical method used in the study were up to thirty-six times above the health standards they were being judged against. Incredibly he chooses to dismiss that as inconsequential stating that it does not invalidate the argument that 1,1,1,2-tetrachloromethane was not exceeded at the limit

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[vii] **BTEX** is an acronym that stands for benzene, toluene, ethylbenzene, and xylenes

of detection. He says: *"Despite this criticism, the testing provides comfort that despite testing for a wide range of substances, the vast majority were not able to be detected."*

It would seem small comfort when the limit of detection is 36 times above the safety level.

METHANE VENTING SIGN, KENYA GASFIELD, TARA REGION
PHOTO COURTESY OF LOCAL RESIDENT

Denial of a problem is rarely the best method of finding a solution to it.

PIPELINE VENT FLARE AND COMPRESSOR FLARE, TARA REGION
PHOTO COURTESY OF LOCAL RESIDENT

It is not the gas that is for the export market which poses a health hazard for the people of the residential estates. It is the mixture of chemicals which are rejected and contaminate the local atmosphere, the soil or water during the process of extraction, cleaning and drying as well as those fugitive emissions which are inadvertently released which are of concern and warrant discussion. So too does the possible mobilisation of microbes in the coal seams.[17]

DEFICIENCIES IN THE ENVIRONMENTAL ASSESSMENT AND TESTING

The environmental air testing programme carried out by QGC, the gas company implicated in the health impacts, was extremely limited and inadequate in every aspect with only 13 air samples being collected. Despite this, many volatile organic compounds were detected. For 26 chemicals the detection level used was significantly higher than the health standard.

Although benzene, a known human carcinogen was detected at a level which demonstrably exceeded its reference criteria, its significance was dismissed. According to The World Health Organisation, because it is carcinogenic, no safe level of exposure to benzene can be recommended.[18] The Ontario standard is 0.13 ppb while the Queensland air standard is 3 ppb, a level 23 times higher. Benzene was detected at Tara at 0.6 ppb. Four other samples reported benzene as <0.17ppb. Disturbingly the author of the Queensland Government report tried to dismiss the significance of this by saying that in suburban Springwood in Brisbane, air monitoring revealed the monthly maximum for benzene from Nov 2011 to October 2012 ranged from 0.9-1.3ppb. Far from this being an explanation or defence, it simply emphasises the poor level of air standards (in relation to world's best practice) which are acceptable to the Queensland government.

The airshed of urban Springwood is, by the Ontario standard, significantly contaminated and therefore associated with an increase in chronic health effects. Turning the airshed of a country area into one which is equally contaminated is not the appropriate solution.

The Queensland Government report recognises that "*the air monitoring programme had important limitations. The total limiting period was 9 days, the methodology resulted in limits of reporting for some analytes that were substantially higher than reference air quality criteria and the monitoring was not designed to identify short term peaks or troughs in air concentrations. It is considered a more strategic air quality monitoring programme could be implemented to provide more useful information….*"

An ad hoc limited odour sampling programme was initiated by the DEHP.

From a toxicological point of view odour does not necessarily correlate with an exposure of concern. However the summa canisters, of which a very limited number were available to the residents over this time period, were released in response to odour events. They detected a cocktail of toxic, irritant, volatile chemicals many of which individually or in combination were capable of causing irritation to the eyes, skin, nasal mucosa and respiratory tract along with systemic effects when absorbed. Carbon monoxide was not one of the chemicals tested following resident initiated sampling. Carbon monoxide is formed by incomplete combustion during flaring and is part of the diesel emissions during drilling and fracking. It is slowly removed from the body, and episodic exposure causes neurotoxic symptoms particularly in children.

Summa canister	Passive
acetone, acrolein, chloromethane, dichlorofluromethane, ethanol, hexane, methylene chloride, methyl ethyl ketone, propene, toluene, vinyl acetate	alpha-pinene, benzene, benzothiazole, cyclohexane, ethyl acetate, ethylbenzene, 2-ethyl-1-hexanol, heptane, hexane, heptadecane, hexadecane, 2-methylbutane, methylcyclohexane, 3-methylhexane, 3 methylpentane, naphthalene, pentane, phenol, tetradecane, tetrachlorethylene, 1,2,4,-trimethylbenzene, toluene, xylene.

TABLE 2 CHEMICALS DETECTED DURING SAMPLING

Some phenols have been shown to have impacts on the endocrine system of living organisms.[19] Endocrine disrupting chemicals can have impacts at very low levels.[20] Other chemicals used by the CSG industry are considered dangerous at concentrations near or below chemical detection limits. These include glutaraldehyde, brominated biocides (DBNPA, DBAN), propargyl alcohol, 2-butoxyethanol (2-BE) and heavy naphtha.[21]

Acrolein, an acute irritant to the eyes, nose, throat, lungs and skin, was reported at 0.5-0.6ppb in three samples. The Ontario 24 – hour criteria is 0.17ppb and the Texas annual criterion is 0.066 ppb. The report dismissed these findings saying it would be incorrect to attribute concern to these 30-60 second samples '*as the exposure period decreases eg from 24 hours (or even annual) to just a few minutes, an acceptable exposure level increases.'* This logic is inexplicable since it presumes that the author knows how long the residents were exposed to acrolein. The exposure did not stop at the end of the 30-60 second grab sample. The report states that passive sampling over three weeks did not identify the presence of acrolein. Drilling, fracking, venting, flaring and road spraying occurred in varying locations and with varying frequency throughout the duration of the Queensland government investigation. One would expect certain chemicals to be associated with the timing of specific processes. The fact that one particular chemical was not detected in a particular 3 week period during the 9 months but was detected at high levels at other times, primarily by way of resident initiated tests, confirms the inadequacy of the testing programme.

For further information on acrolein, refer to the U.S. Department of Health And Human Services document 'Toxicological profile for Acrolein'.[22]

In summary the Queensland Government report appears to be at best a highly flawed inadequate investigation, unable to draw conclusions due to lack of appropriate data – at worst it could be interpreted as a cynical exercise to dismiss significant health concerns in the face of large financial profits.

EXPLORING THE EVIDENCE

The Queensland Health report did not undertake an extensive review of the evidence in relation to the health impacts of unconventional gas.

The underlying questions remain:

1. Are these health and well-being concerns legitimate?
2. Is there any independent supporting evidence to link these symptoms to unconventional gas exposure?

A search of the literature shows that there is a growing body of evidence documenting the adverse health impacts of unconventional gas development.

McKenzie et al (May 2012)[23]

This study found that residents living ≤ ½ mile from wells are at greater risk for health effects from natural gas developments (both cancer and non-cancer) than residents living further away. Subchronic exposures to air pollutants during well completion activities presented the greatest potential for health effects.

Colburn et al (September2011)[24]

The technology to recover natural gas depends on undisclosed types and amounts of toxic chemicals….. More than 75% of the chemicals could affect the skin, eyes and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40% to 50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations. These results indicate that many chemicals used during the fracturing and drilling stages of gas operations may have long term health effects that are not immediately expressed.

It should be noted that many of the chemicals used for drilling and hydraulic fracturing in Australia have not been assessed for their impacts on human health and the environment. Of the 23 identified as commonly used 'fracking' chemicals, only 2 had been assessed by the national regulator, National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and neither was for their use in CSG.[25]

Shale gas roulette (October 2012)[26]
A study undertaken in Pennsylvania

25 most prevalent symptoms: fatigue (62%), nasal irritation (61%), throat irritation (60%), sinus problems (58%), eyes burning (53%), shortness of breath (52%), joint pain (52%), feeling weak and tired (52%), severe headaches (51%), sleep disturbance (51%), lumbar pain (49%), forgetfulness (48%), muscle aches and pains (44%), difficulty breathing (41%), sleep disorders (41%), frequent irritation (39%), weakness (39%), frequent nausea (39%), skin irritation (38%), skin rashes (37%); depression

(37%), memory problems (36%), severe anxiety (35%), tension (35%), and dizziness (34%)

"Contaminants that are associated with oil and gas development are present in air and water in areas where residents are experiencing health symptoms consistent with such exposures","Permitting widespread gas development without fully understanding impacts is risking public health"

Krzyzanowski (June 2012)[27]

Northeast British Colombia has experienced increased rates of cancer and other illness due to contaminants and stressors associated with unconventional gas.

TEDX (November 2012)[28]

Weekly air sampling for one year revealed that the number of non-methane hydrocarbons (NMHCs) and their concentrations were highest during the initial drilling phase. Methylene chloride, a toxic solvent not reported in products used in drilling or hydraulic fracturing, was detected 73% of the time; several times in high concentrations. Many of the NMHCs had multiple health effects, including 30 that affect the endocrine system, which is susceptible to chemical impacts at low concentrations, far less than government safety standards. Selected polycyclic aromatic hydrocarbons (PAHs) were at concentrations greater than those at which prenatally exposed children in urban studies had[29] lower development and IQ scores.

NIOSH (May 2012)[30]

The American occupational health and safety organisation has highlighted the serious risks of cancer and chronic lung disease from silica (which is used in fracking and which the industry regularly innocuously refers to as "sand" There are risks of inhalation at every stage through quarrying, road transportation, and for workers on the well sites as well as residents nearby). Following on from their research they issued Silica sand Hazard Alert in April 2012.

American Academy of Pediatrics (December 2012)[31]

This document lists 12 chemicals used in fracking or found in the brine drawn out of the well which are of particular concern to the authors. They state "*most physicans will recognize that these are highly toxic substances*"

Below is an extract regarding 4 of the 12 chemicals.

ACETIC ANHYDRIDE- Severe irritation of eyes, upper respiratory mucous membranes and skin to very low concentrations. Permanent corneal scarring. Explosion related injuries

ETHYLENE GLYCOL- acute: neurotoxicity, cardiopulmonary effects, renal. Low dose effects, eyes, nose and throat.

TOLUENE- Noncancer acute effects: Neurotoxic, fatigue, drowsiness, headaches, nausea, unconsciousness. Noncancer chronic effects: CNS depression, ataxia, tremors, cerebral atrophy, impaired speech, hearing and vision, Inflammation and degeneration of nasal epithelium, pulmonary lesions. Maternal reproductive: increased spontaneous abortions. Developmental: neurotoxicant, attention deficit, cranio-facial and limb anomalies.

BENZENE- IARC Group 1 Carcinogen: Leukemia (acute myelogenous). Noncancer acute effects: Neurological: drowsiness, headaches, unconsciousness, convulsions. Skin, eyes and upper respiratory tract Irritation GI: Nausea, vomiting. Noncancer chronic effects: Blood dyscrasias, aplastic anemia, excessive bleeding, leukopenia Immunosuppression. Developmental: low birth weight, delayed bone formation………..

CONCLUSION

The unconventional gas industry has been allowed rapid, unfettered expansion in Queensland within recent years without taking into account the consequences to public health.

Experts in human health have been excluded from all decision making regarding CSG and other types of unconventional gas development in Australia despite this controversial industry being permitted and imposed in close proximity to human habitation. Studies documenting the serious health consequences have been already been published overseas. It is essential that medical specialists relating to all aspects of human health, (paediatricians, oncologists, endocrinologists, neurologists, toxicologists, obstetricians and others) are urgently involved in decision making relating to the unconventional gas industry.

The population of the rural residential estates on the Western Downs near Tara is among the most densely settled cohort in Australia to have, so far, lived in close proximity to intensive unconventional gas development. Without any formal system in place to monitor the effect on human health of this industrial process, they have in effect become the sentinel population, the human equivalent of the canary in the coal mine.

This study shows a pattern of reported symptoms that is very concerning. In particular, a high percentage of the residents surveyed had symptoms of which could relate to neurotoxicity, including tingling, paraesthesia, numbness, headaches, difficulty concentrating and extreme fatigue. Of particular concern was the high percentage of symptomatic children, with paraesthesia being reported for almost a third of surveyed children to age 18, and headaches being reported for more than 70%. This is not a pattern of reported illness which is expected and should prompt an urgent and comprehensive response.

There are serious questions to be answered by the previous Queensland Government in relation to their due diligence in the process of permitting these gas developments. I believe there are also serious questions to be answered by the current Queensland Government in regard to their due diligence in investigating the harm that was reported to them by residents of the residential estates.

It is vitally important that the politicians of Australia, both state and federal, understand that they have a duty of care to the citizens of this nation. If the health implications of the unconventional gas industry continue to be ignored and the industry is allowed to develop along its current path, the potential exists for serious and widespread harm to human health across Australia.

RECOMMENDATIONS

1) A fully funded comprehensive medical assessment of residents currently living in proximity to unconventional gas development should be carried out as a matter of urgency. The residents of the rural residential estates and surrounding neighbourhoods on the Western Downs are an obvious first priority, but it should not be forgotten that throughout rural Queensland there are even more remote locations where isolated families have been living in close proximity to gas development.

2) Considering the toxins that residents could potentially have been exposed to, fully funded, long term epidemiological studies are necessary to track the health of people exposed to unconventional gas over the next several decades. These studies should be set up as a matter of urgency. It is important to include people who may already have left the area because of health concerns. The census of 9th august 2011 could provide data on residency at that point in time. The long term health of workers in the industry requires long term surveillance also. In this case baseline health studies are already available in the form of pre-employment medicals. For their own future reference, I would advise all workers to acquire a copy of their pre-employment medical under freedom of information.

The cause of human health impacts may not be simple, that is a single chemical culprit, but be the cumulative impact over time of several related or unrelated chemicals. It is the interactions of a mixture of chemicals both outside and inside the body which warrant investigation. If one compound prevents the breakdown or excretion of other compounds from the body then unforeseen toxicity can result. If solvents are part of the mix, then the blood brain barrier may be compromised, with serious and unpredictable consequences.[viii]

3) Health impact assessments must be an integral part of any and every unconventional gas development. No new permit should be issued without one, and health impact assessments should be carried out for every development already in place.

[viii] Dr John Polglase private email/Dr David Brown PSE

4) Comprehensive air and water monitoring (an open, ongoing and unlimited information loop) is essential. If we are looking at possible non beneficial human health impacts we need to look at all the gases and volatiles both natural and derived emitted via well drilling, gas and pipeline valves, leaking wellheads, flaring, and other processes involved in gas collection/purification/refining to export specifications. This monitoring is urgently required. It must be independent, unbiased, fully funded and available for public scrutiny preferably in real time and in electronic form.

5) Gas companies must be required to fully and openly disclose in a timely manner, all chemicals, and all quantities of chemicals, used or planned to be used for drilling, fracking, cleaning, dehydration, and other processes at every gas facility. All historical results they have of analyses of air, soil and water should be available for public scrutiny.

6) The federal government must develop legislation to protect public health in general but from the impacts of unconventional as development in particular. Public health legislation occurs at state level and it is important to have a unified standard and approach to public health across Australia.

7) Thought must be seriously given to what the future for the unconventional gas industry should be in Australia. Politicians must engage in public debate. Consideration of the health impacts of unconventional gas development should be added to the national debate on its future.

The questions which require answers are:

a) Is it simply enough to provide buffers around residential developments? If so how far should the buffer extend? It should be noted that New South Wales's proposed 2km buffer from a residential development of 1000 people or more would not have protected a single resident of the Tara estates.

b) If it is confirmed that the health of the residents of the Tara estates is impacted, should they be rehoused? If so where and at cost to whom?

c) What would the effect of loss or contamination of agricultural land and possible insecurity of food supply have on the future health of the population?

d) What would the effect of degrading or depleting the aquifers of the Great Artesian Basin and possible insecurity of fresh water supply have on the health of Australia?

e) If methane emissions accelerate global warning what impact will that have on our health?

If these questions are still unanswered should the activities of an industry which was imposed upon communities in Queensland in such controversial circumstances remain unchecked? Or is this the asbestos equivalent of the 21st century and no matter how unpalatable and how unprofitable, difficult decisions need to be made.

APPENDIX A – QUESTIONNAIRES

Part 1- Environmental details of each household

CSG HEALTH QUESTIONNAIRE

Name Survey number

Date

Address

Occupants

	Name	age	Relationship

How long have you lived on the property?

House structure

Single	Double storey	wooden	Brick/ slab	other

Size of property

Power source

Mains electricity	Solar	Generator	Other

Name survey no

Water supply

	Drinking	cooking	Washing dishes	Washing clothes	Bathing	Vegetable garden	Domestic animals	other
Town								
Trucked								
Bottled								
Rainwater tanks								
Dam								
Bore								
River/creek								
other								

Water storage, type of tanks

How is water treated before use?

Home environment

Air conditioner	Air purifier	Central heating(gas) (oil)	Gas stove
Electric stove	Fireplace	Wood stove	humidifier

Have you recently acquired new furniture, carpet or refinished furniture?

Yes, no

Are pesticides or herbicides (bug or weed killers; flea and tick sprays, collars powders or shampoos) used in your home or garden, or on pets?

Yes, no

To your knowledge, when did CSG activity start?

Closest infrastructure	distance /quantity	Direction
Wells		
Ponds		
High point valves		
Low point valves		
Compressor stations		
Dehydration plants		
Pipelines		
other		

Name Survey no

Usual wind directions

Relative to your home, which companies have gas infrastructure and in which direction?

On or near your property are you aware of the following .... And if so since when?

Odours	Unusual cracking of soil	Bubbling in puddles	Bubbling of river/ creek

Do you have domestic animals/birds on the property?

Cattle	sheep	goats	Pigs	chickens	ducks	Dogs	cats	Pet birds	other

Have you noticed any unusual illness amongst the livestock?

Birds – loss of feathers, unexpected death

Dogs- rashes, change in temperament/ apparent pain / unexpected death/

Have you noticed any change in health or numbers of native animals, birds or frogs?

If so what and since when?

Part 2- Individual questionnaire for each person within each household

Past history questionnaire

Name survey no

Health prior to CSG development

DIAGNOSIS	Yes	No
asthma		
allergies		
eczema		
COPD		
Heart attack		
stroke		
Peripheral neuropathy		
Carpal tunnel		
Diabetes		
Epilepsy		
Other neurological problem		
Skin cancer		
Other cancer		
Congenital heart disease		

Conditions diagnosed since CSG development

Name Survey no

Do you believe your health has been adversely affected by CSG? yes no uncertain

If yes, explain how you feel your health is impacted. Describe symptoms. Relate specific incidents / frequency and duration of exposures / frequency and duration of symptoms/ time frame of symptoms related to weather events and known specific gas field activities. Describe odours- if there are different odours do you notice any difference in symptoms?

If medical attention sought: where, from whom and how frequently?

What was the outcome?

If medical attention not sought, reasons why not

Child age 6-adult questionnaire

Name. Survey number

Age male female smoker non-smoker date

	In the two years prior to CSG development how often did you suffer from;				Since CSG development(in the past 1-2 years) how often have you suffered from;			
	Never	Occasionall y	often	Constantl y	Never	Occasionall y	often	Constantl y
Eye								
Streaming eyes								
Nasal burning								
Blood from nose on wiping								
Spontaneous nose bleeds								
Mild headaches								
Severe headaches								
Cough								
Chest discomfort								
Chest tightness								
Difficulty breathing								
Severe chest pain								
Irregular heartbeat								
Skin irritation								
Rashes								
dizzyness								
Severe fatigue								
Difficulty concentrating								
Difficulty sleeping								
Depression/ anxiety								
weakness								
forgetfulness								
nausea								
vomiting								
Stomach pains								
Muscle pains/ spasms								
Tingling /numbness hands / feet/ head								

seizures								
Collapse								
Sore joints								

Never:- never. Occasionally :– has happened ever (in the time frame), few times, sporadic. Often:- recurring, regular, frequent. Constantly :- at least twice per week.

Age 0-5 questionnaire

Infants / Children

Name survey number

Age male female date

History by mother / father /

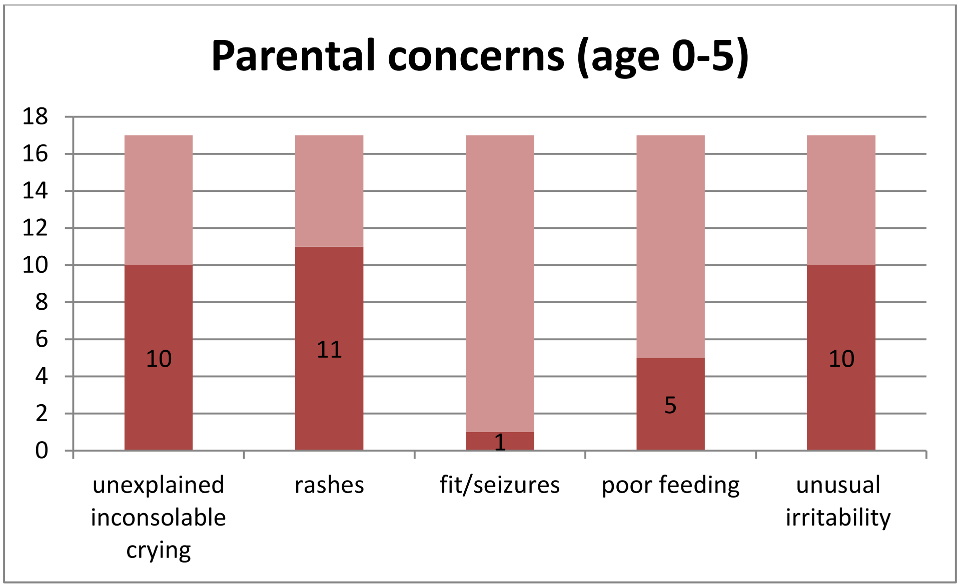
Have you noticed or been concerned by any of the following:

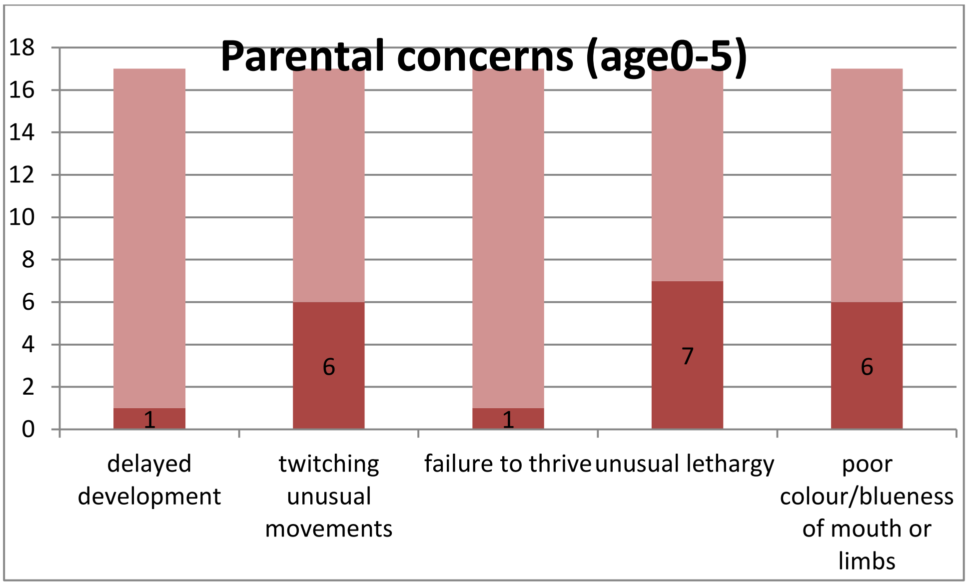
Unexplained inconsolable crying	Rashes	Fits /seizures	Poor feeding
Unusual irritability	Delayed development	Twitching /unusual movements	Failure to thrive
Unusual lethargy	Poor colour /blueness around mouth or limbs	If walking, unusual clumsiness unsteadiness or falls	Unusual susceptibility to infections
Eye irritation	Streaming eyes	Blood from nose	
Cough	Difficulty breathing	Unexplained vomiting	Difficulty sleeping
Headaches	Stomach pains	Sore limbs	Muscle spasms
Tingling hands feet head	Burning nose		

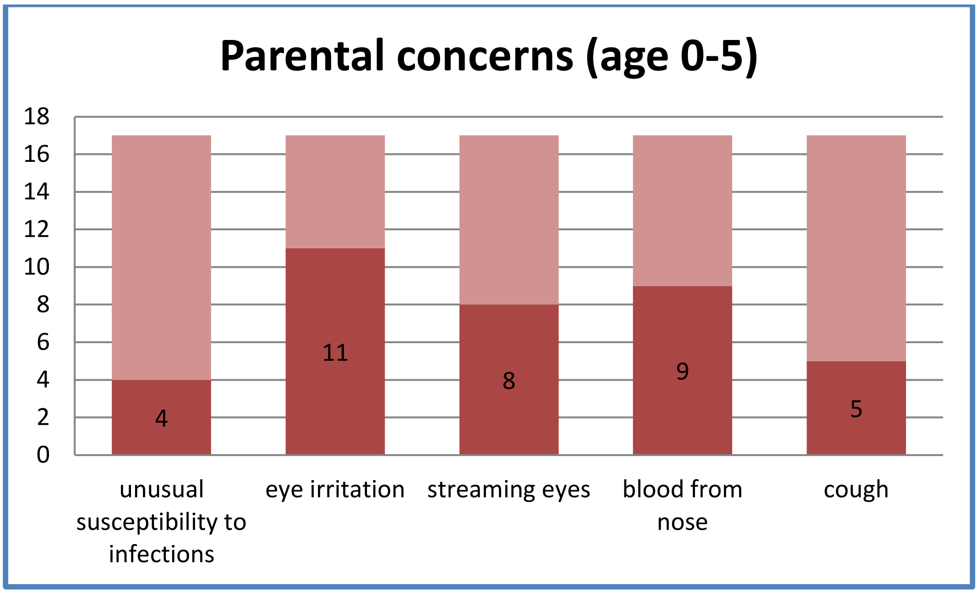
APPENDIX B – DATA CHARTS

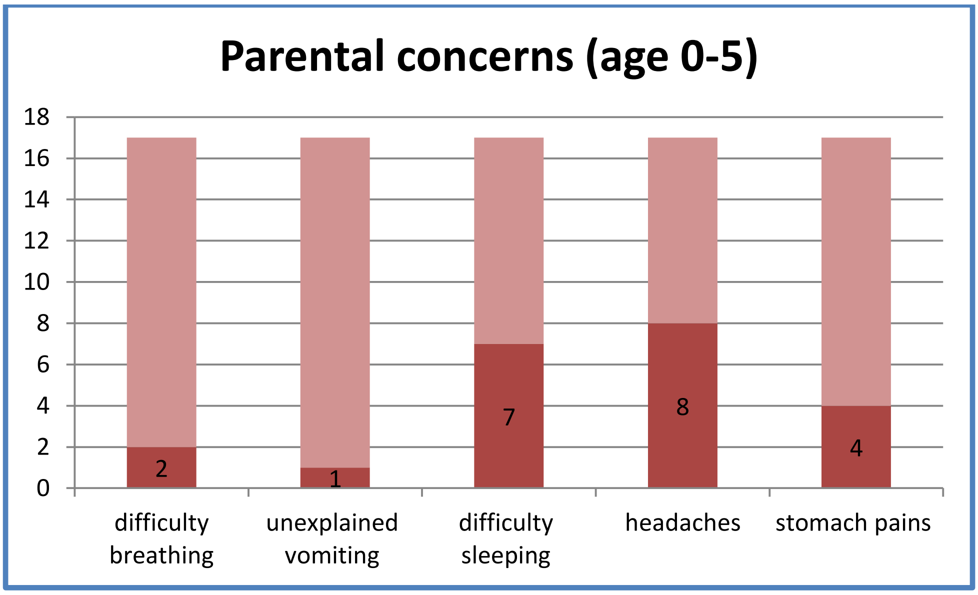
Parental Concerns age 0-5

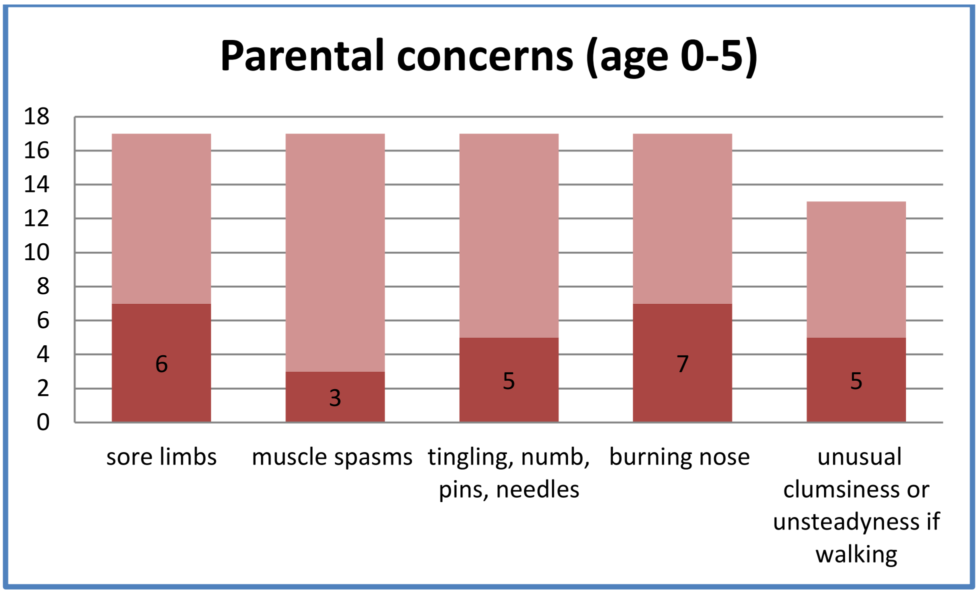
Bar Charts



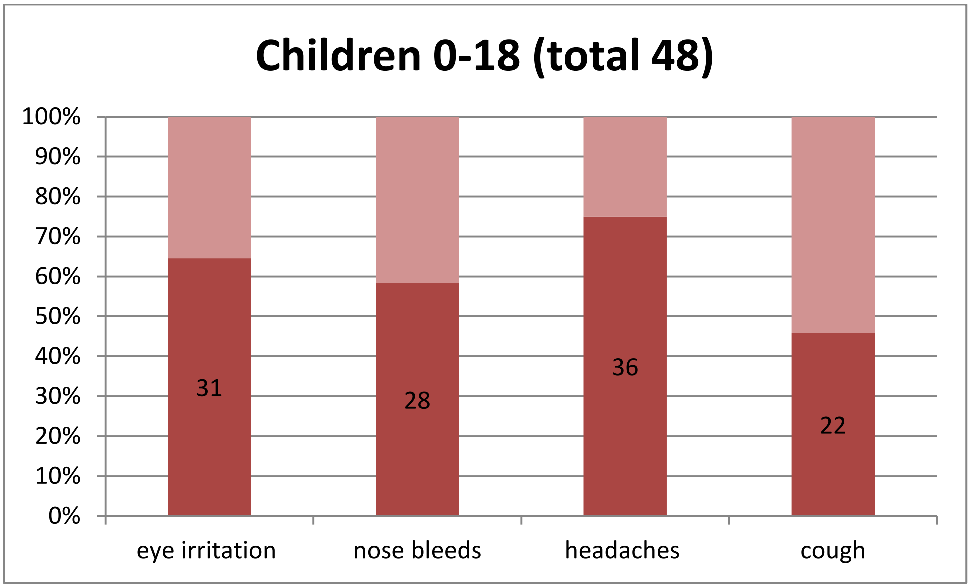


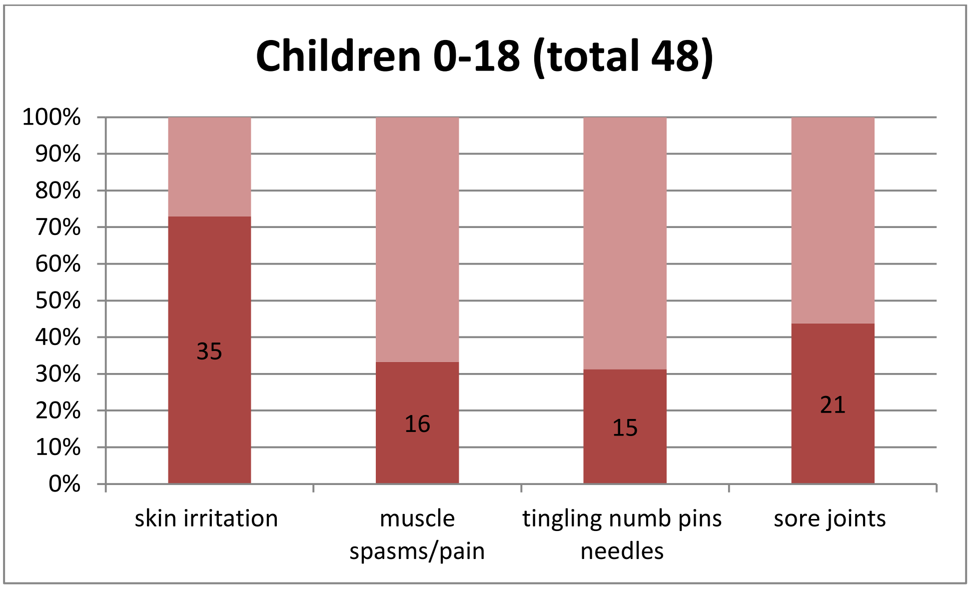

Parental concerns (age 0-5)
18
16
14
12
10
8
6
4
2
0
4
11
8
9
5
unusual susceptibility to infections
eye irritation
streaming eyes
blood from nose
cough


Parental concerns (age 0-5)
18
16
14
12
10
8
6
4
2
0
2
1
7
8
4
difficulty breathing
unexplained vomiting
difficulty sleeping
headaches
stomach pains

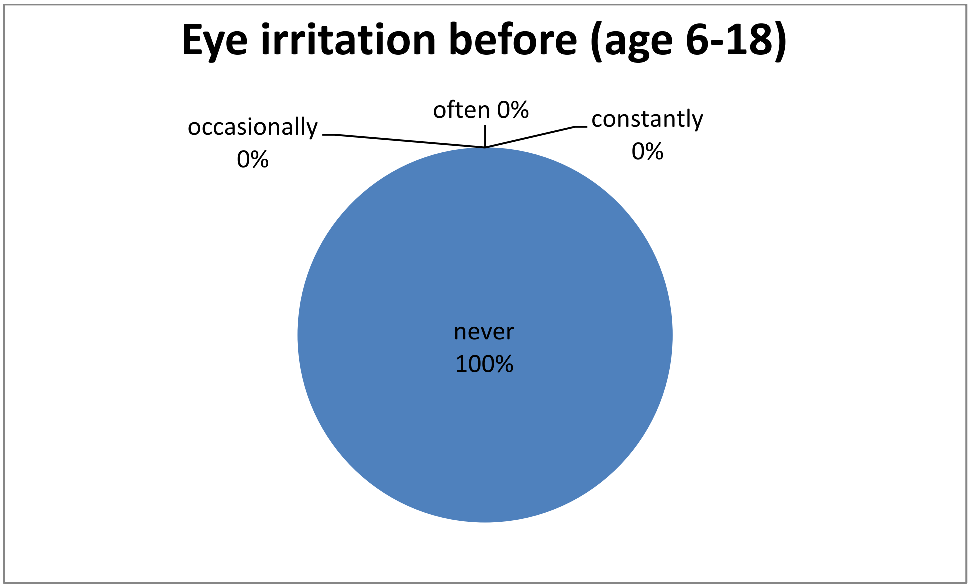

Parental concerns (age 0-5)
18
16
14
12
10
8
6
4
2
0
6
3
5
7
5
sore limbs
muscle spasms
tingling, numb, pins, needles
burning nose
unusual clumsiness or unsteadyness if walking

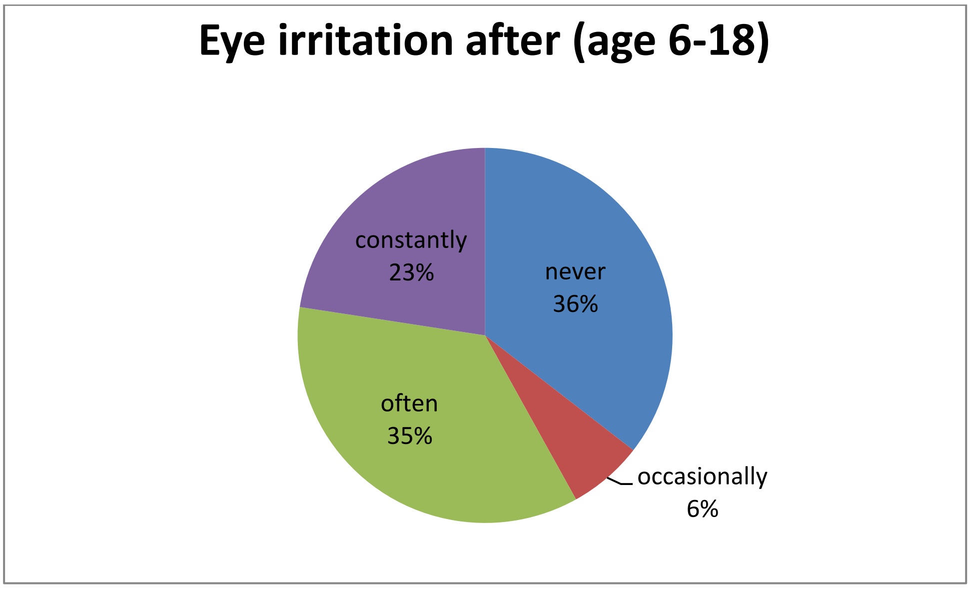
Children age 0-18, Percentage symptomatic – Bar Charts

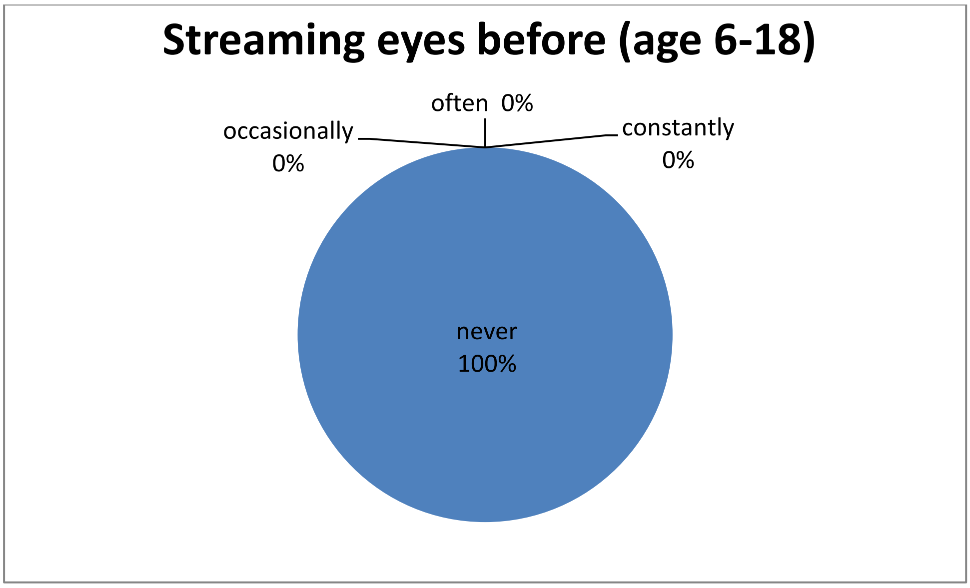


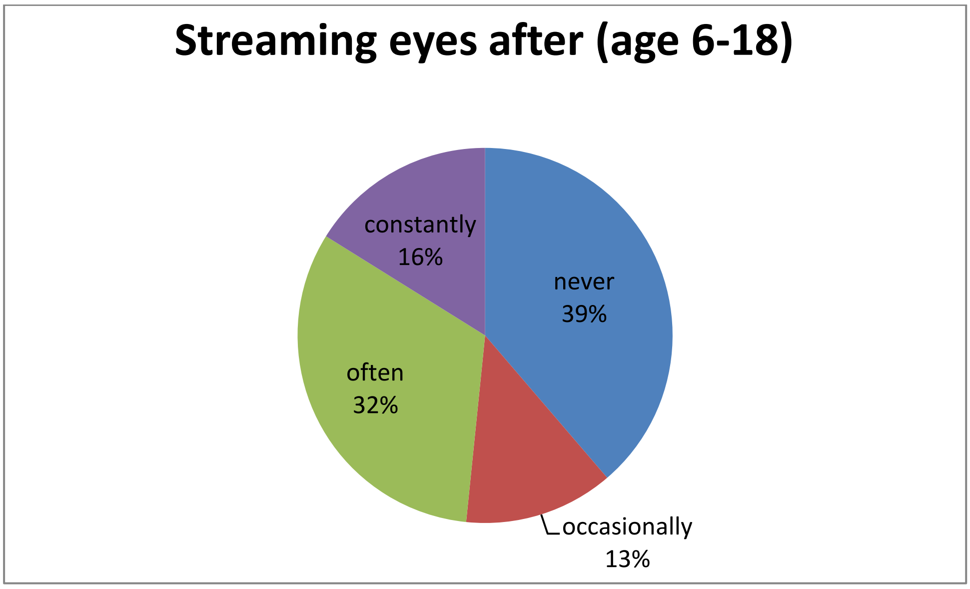


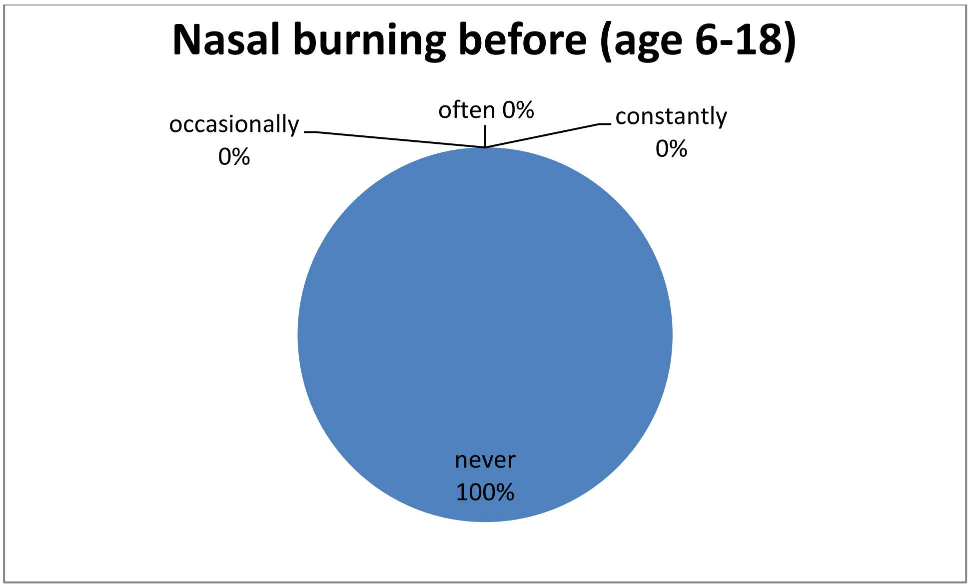
Age 6-18 Symptoms reported before and after Coal Seam Gas exposure – Pie Charts

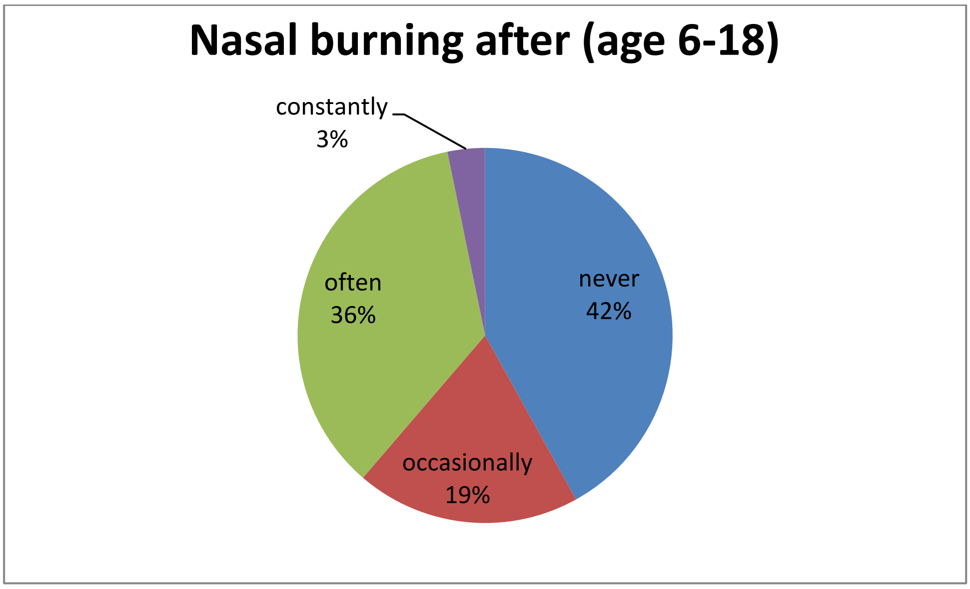


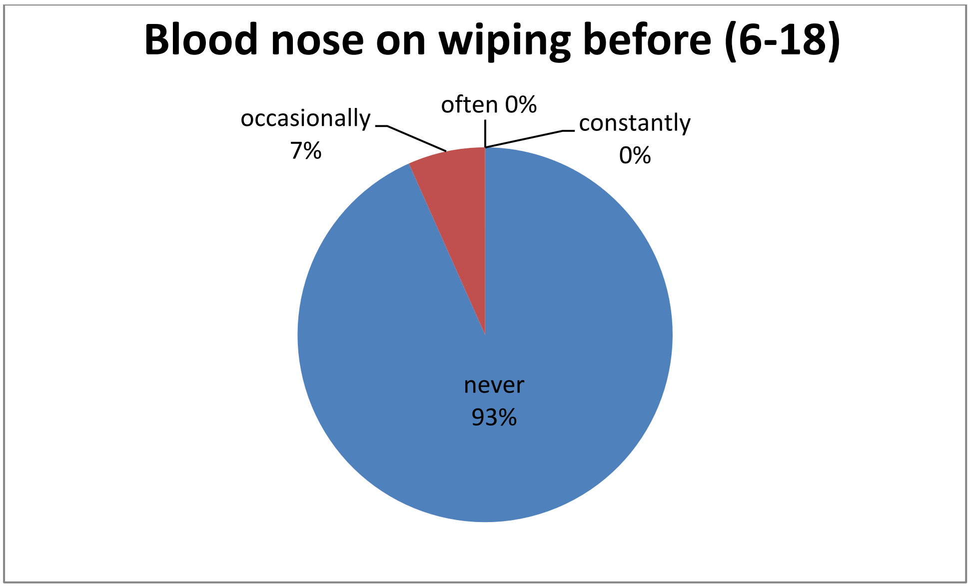


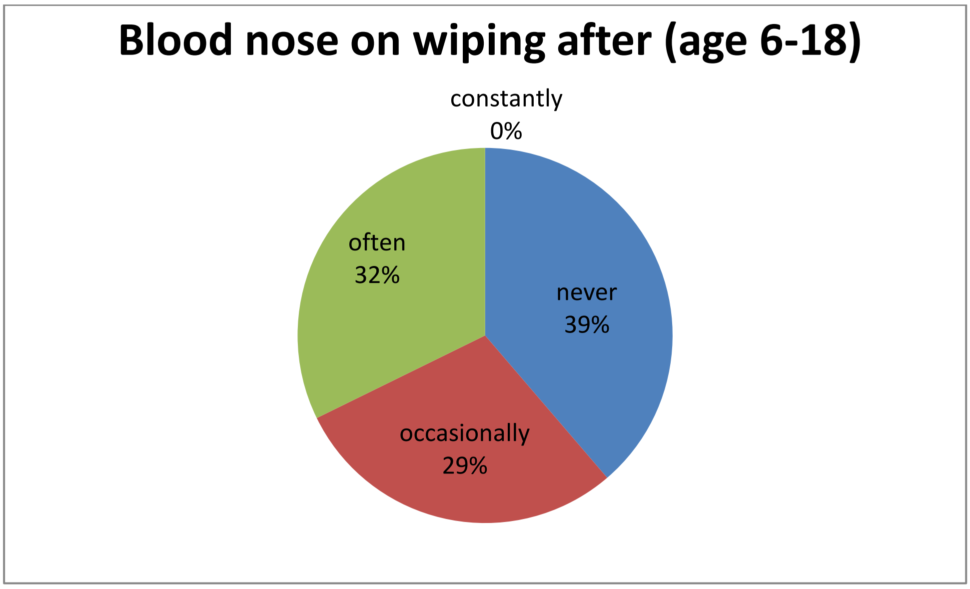

Streaming eyes before (age 6-18)
often 0%
occasionally 0%
constantly 0%
never 100%

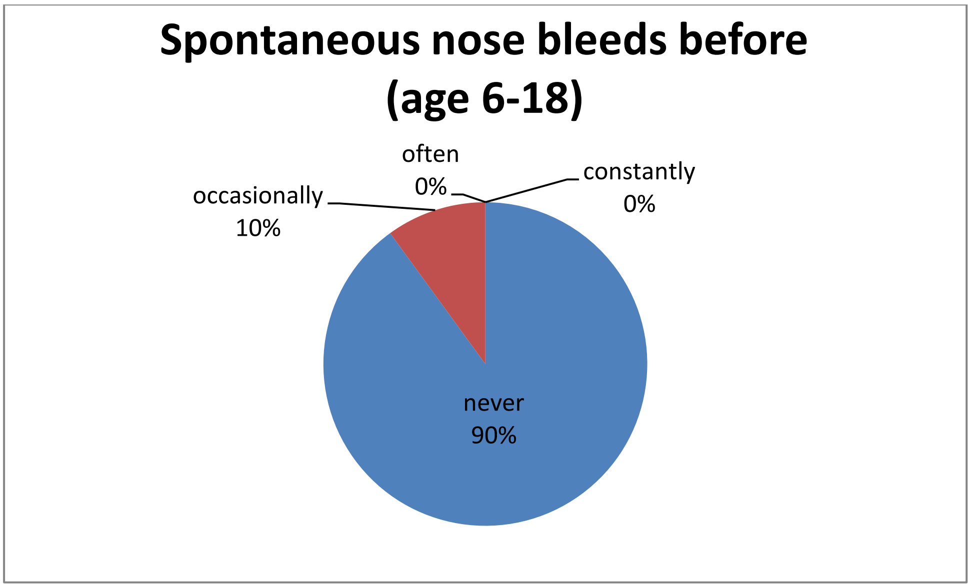

Streaming eyes after (age 6-18)
constantly 16%
never 39%
often 32%
occasionally 13%

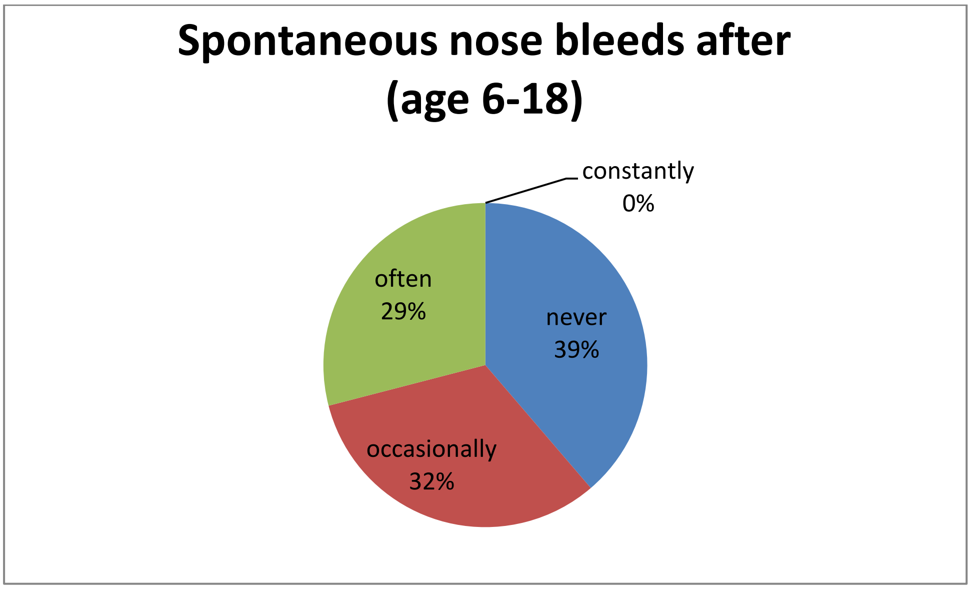

Nasal burning before (age 6-18)
occasionally 0%
often 0%
constantly 0%
never 100%

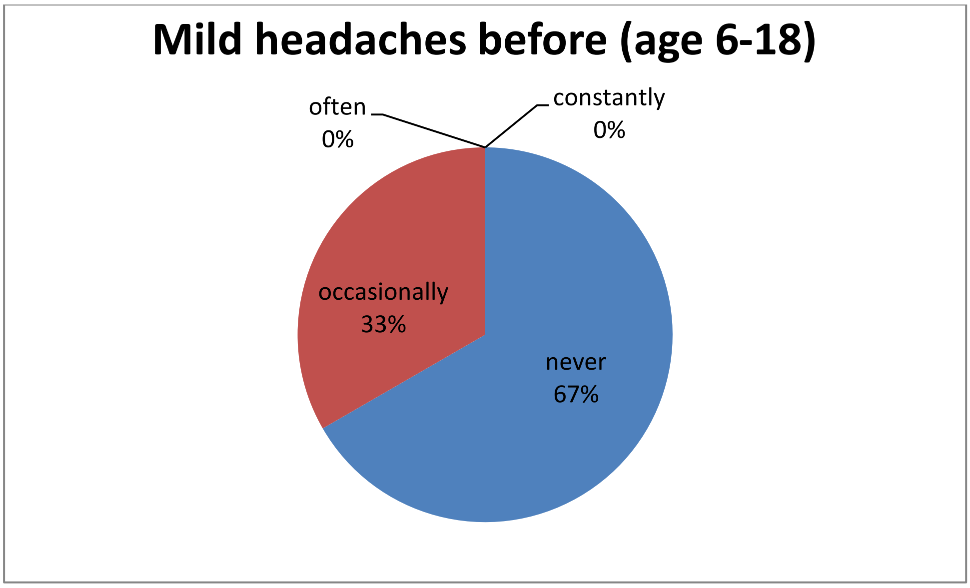

Nasal burning after (age 6-18)
constantly 3%
often 36%
never 42%
occasionally 19%

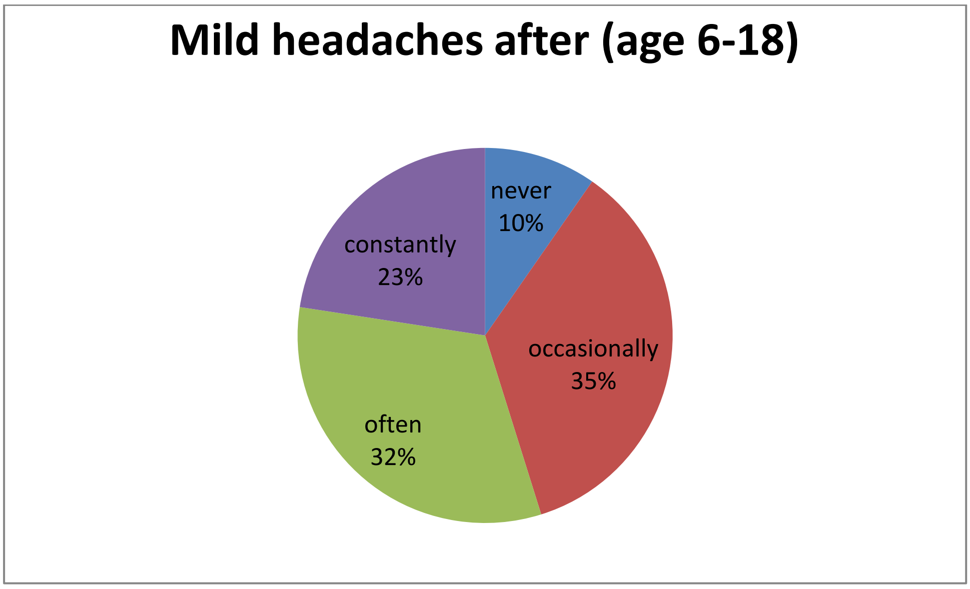

Blood nose on wiping before (6-18)
occasionally 7%
often 0%
constantly 0%
never 93%

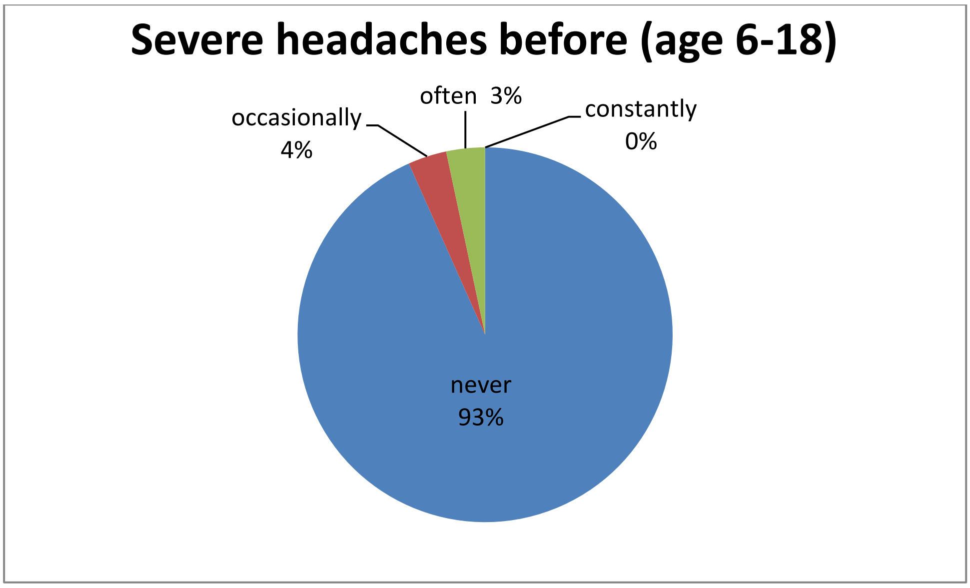

Blood nose on wiping after (age 6-18)
constantly 0%
often 32%
never 39%
occasionally 29%

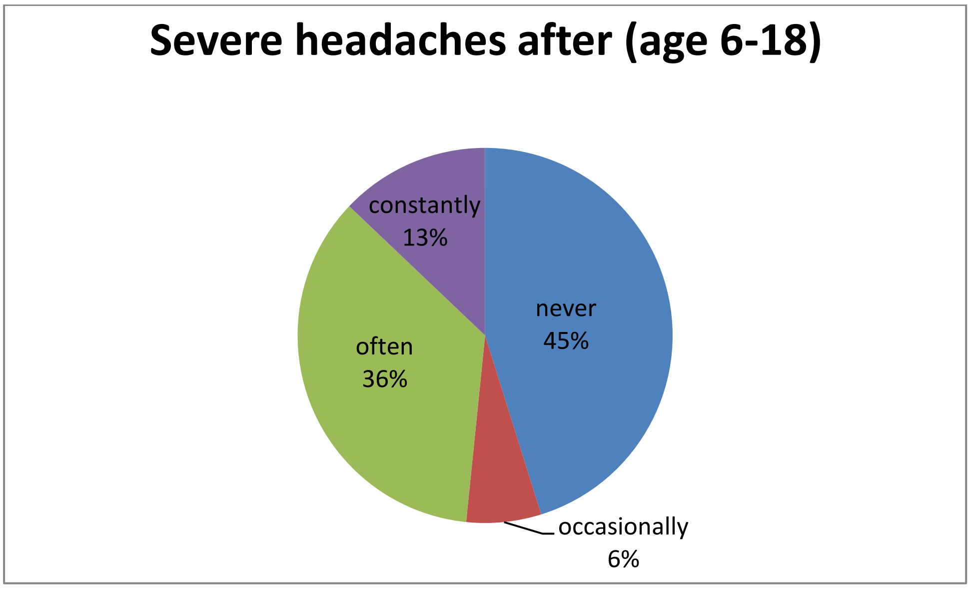

Spontaneous nose bleeds before (age 6-18)
often 0%
constantly 0%
occasionally 10%
never 90%

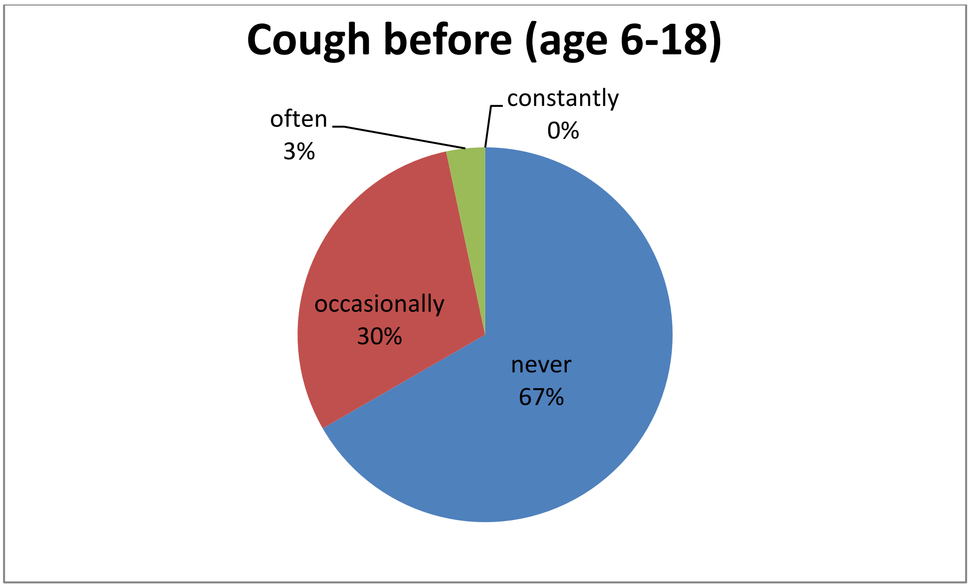

Spontaneous nose bleeds after (age 6-18)
constantly 0%
often 29%
never 39%
occasionally 32%

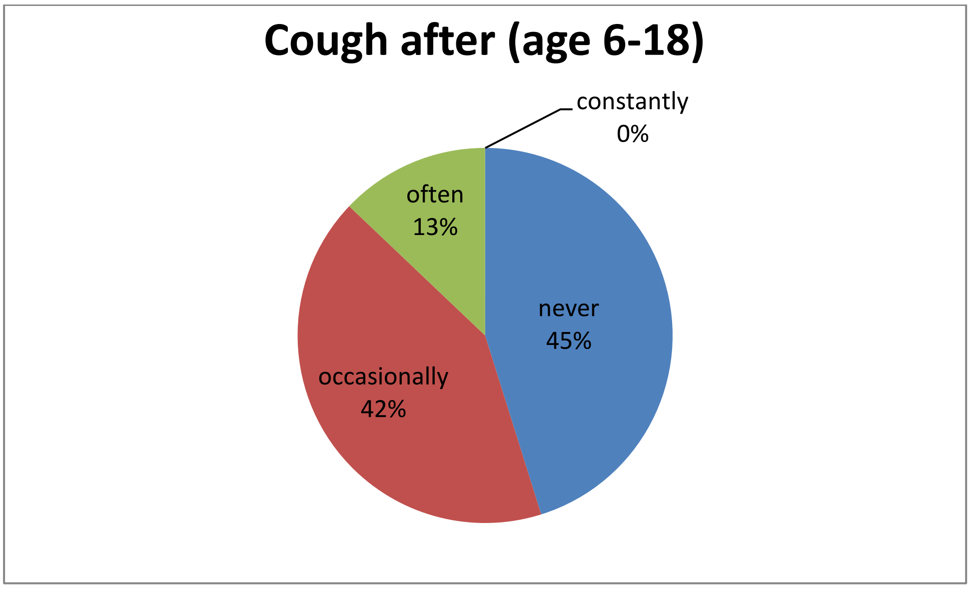

Mild headaches before (age 6-18)
often
0%
constantly
0%
occasionally
33%
never
67%

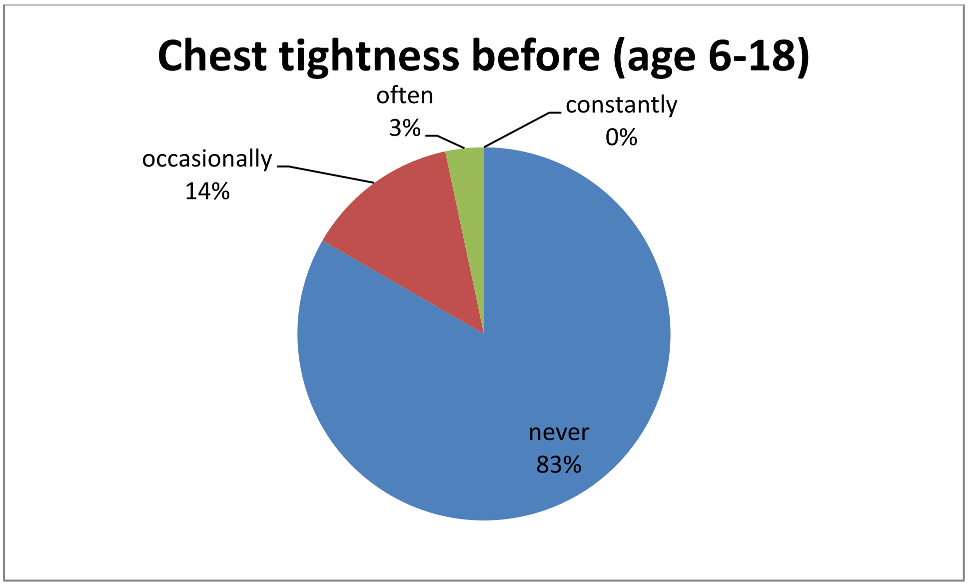

Mild headaches after (age 6-18)
never
10%
constantly
23%
occasionally
35%
often
32%

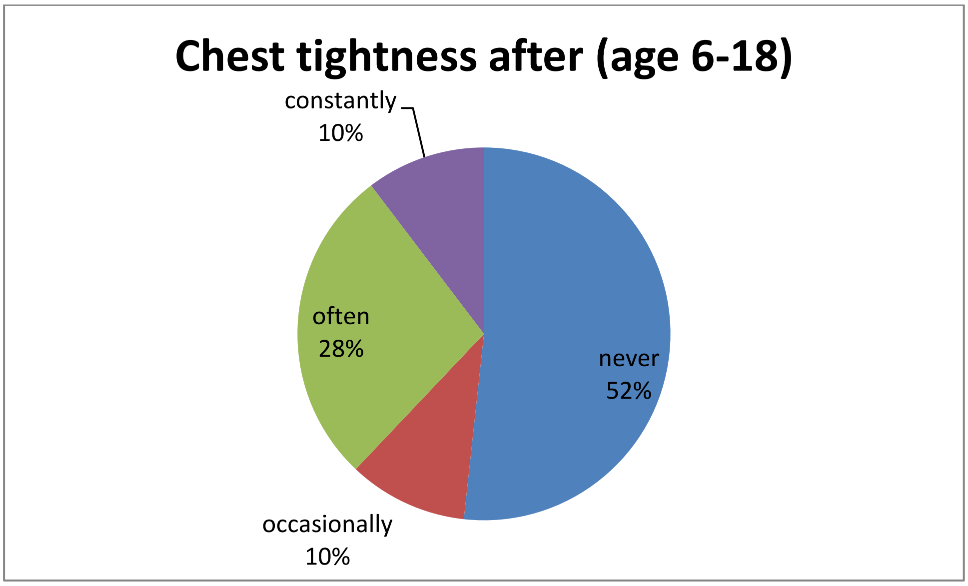

Severe headaches before (age 6-18)
often 3%
occasionally 4%
constantly 0%
never 93%

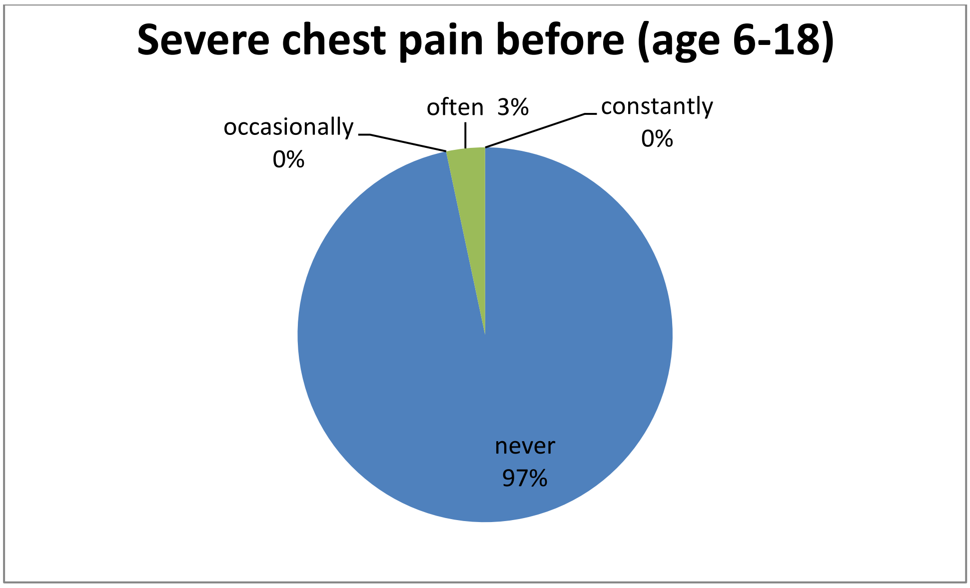

Severe headaches after (age 6-18)
constantly 13%
never 45%
often 36%
occasionally 6%

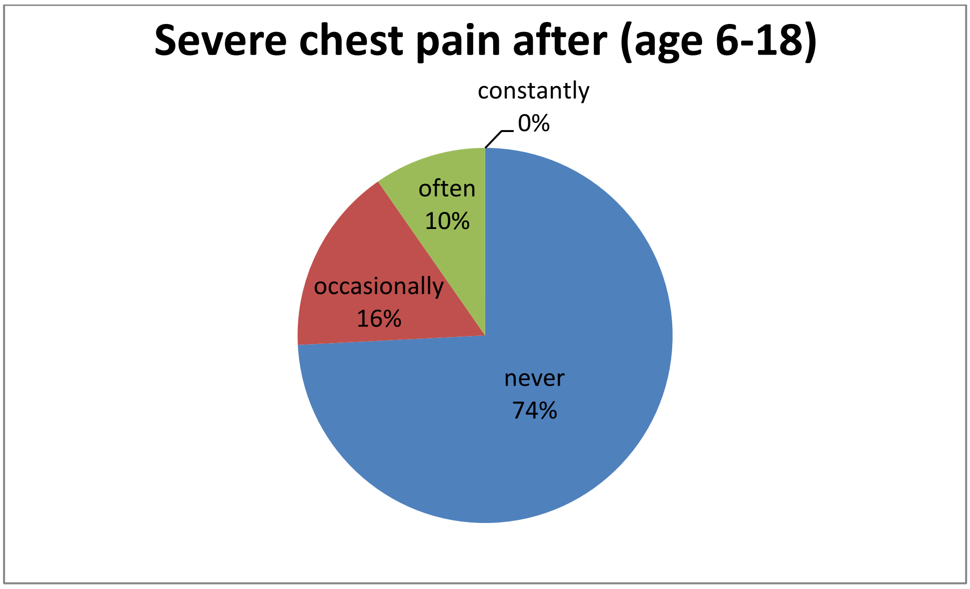

Cough before (age 6-18)
constantly
0%
often
3%
occasionally
30%
never
67%

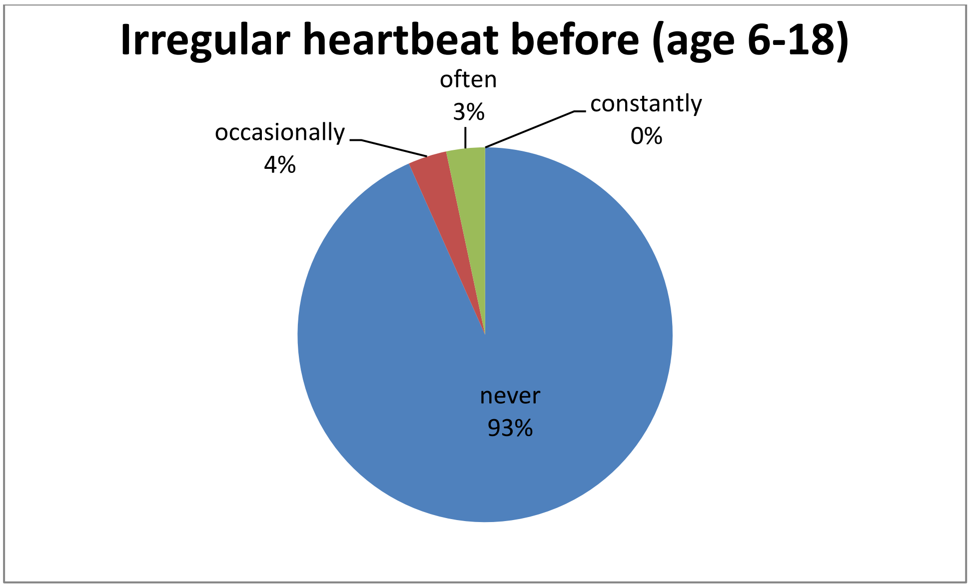

Cough after (age 6-18)
constantly
0%
often
13%
never
45%
occasionally
42%

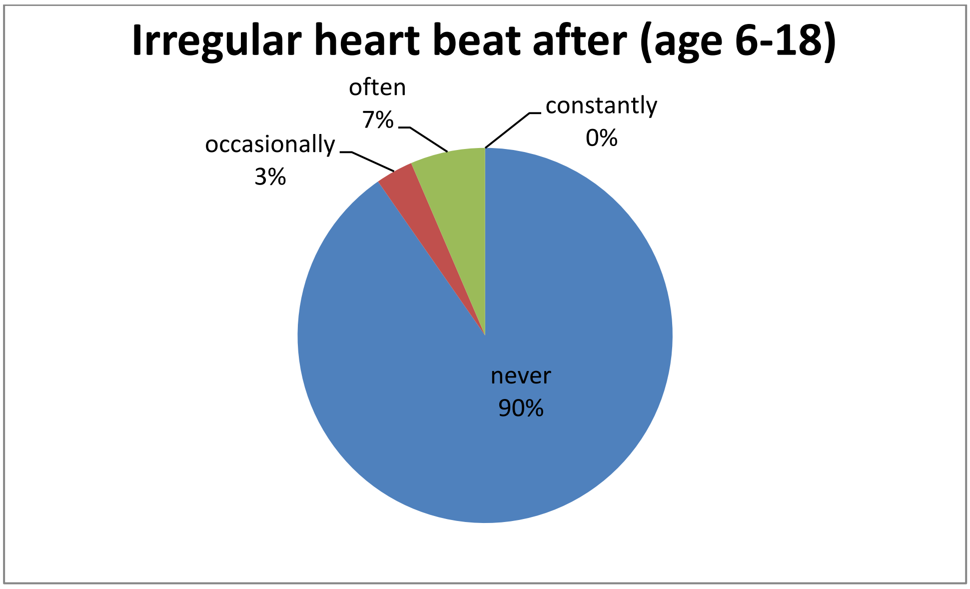

Chest tightness before (age 6-18)
often
3%
constantly
0%
occasionally
14%
never
83%

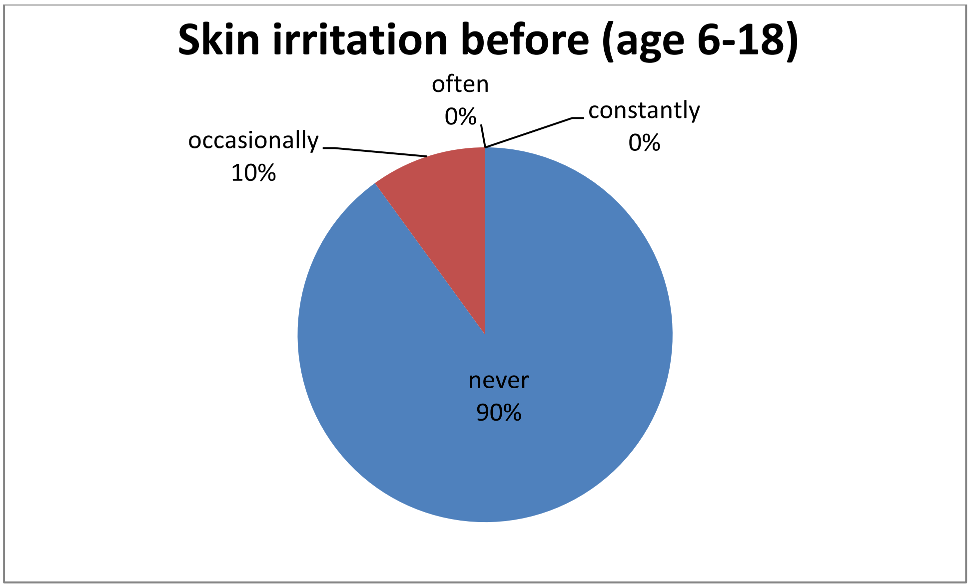

Chest tightness after (age 6-18)
constantly
10%
often
28%
never
52%
occasionally
10%

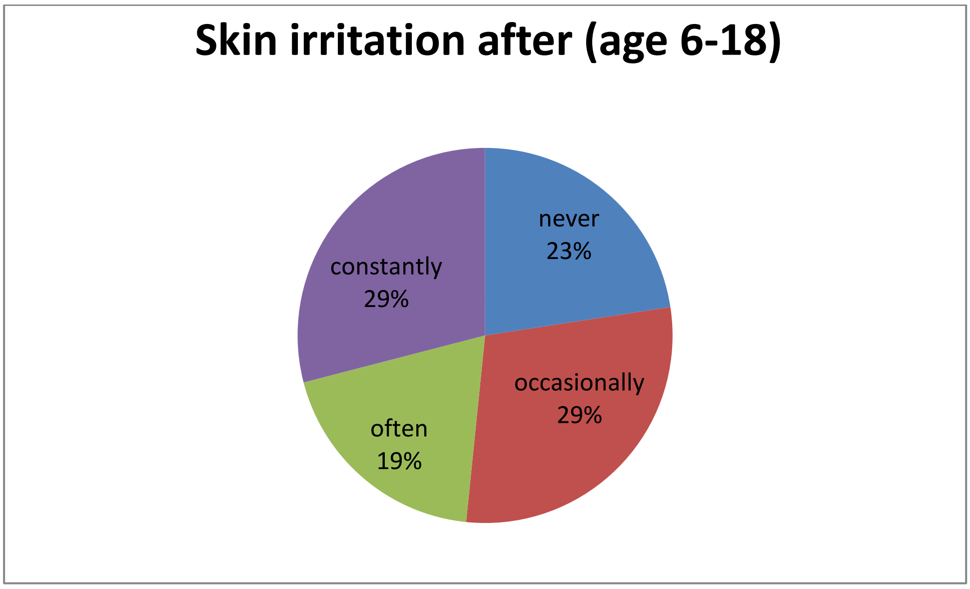

Severe chest pain before (age 6-18)
occasionally 0%
often 3%
constantly 0%
never 97%

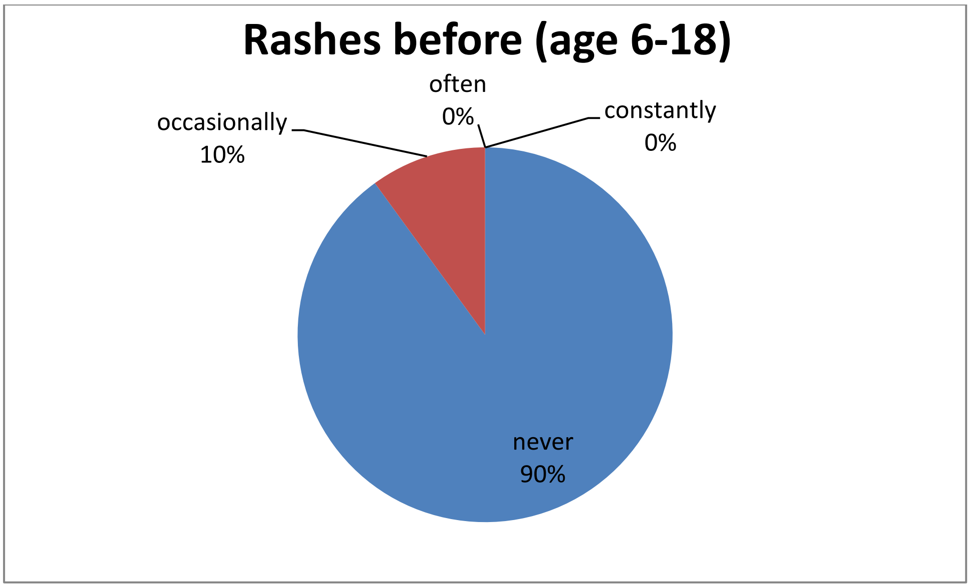

Severe chest pain after (age 6-18)
constantly 0%
often 10%
occasionally 16%
never 74%

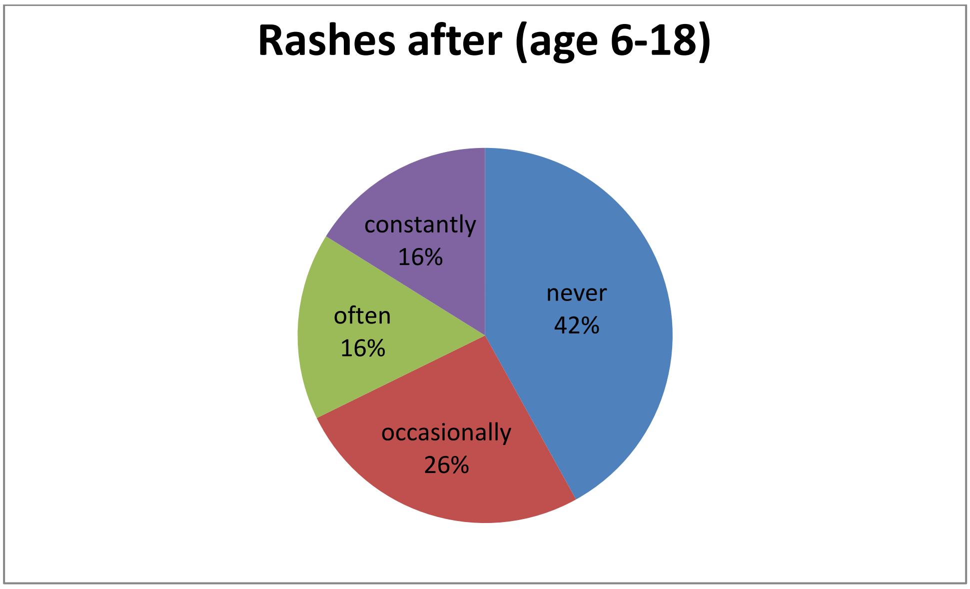

Irregular heartbeat before (age 6-18)
often
3%
constantly
0%
occasionally
4%
never
93%

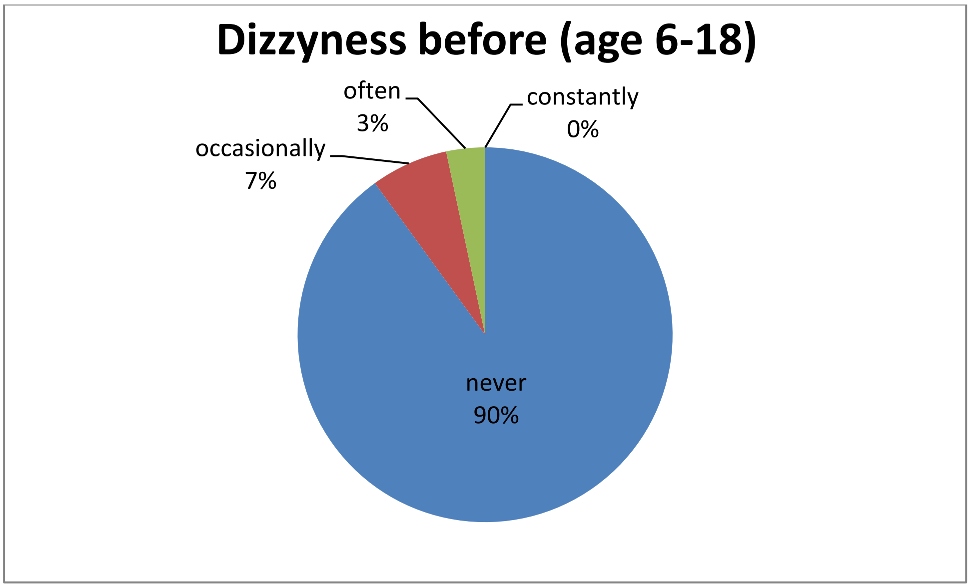

Irregular heart beat after (age 6-18)
often
7%
constantly
0%
occasionally
3%
never
90%

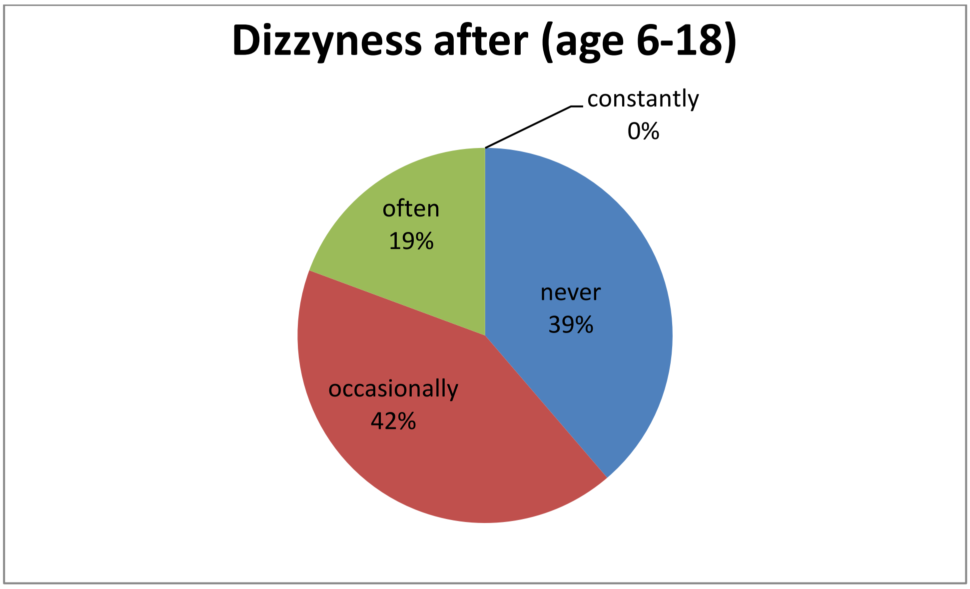

Skin irritation before (age 6-18)
often
0%
constantly
0%
occasionally
10%
never
90%

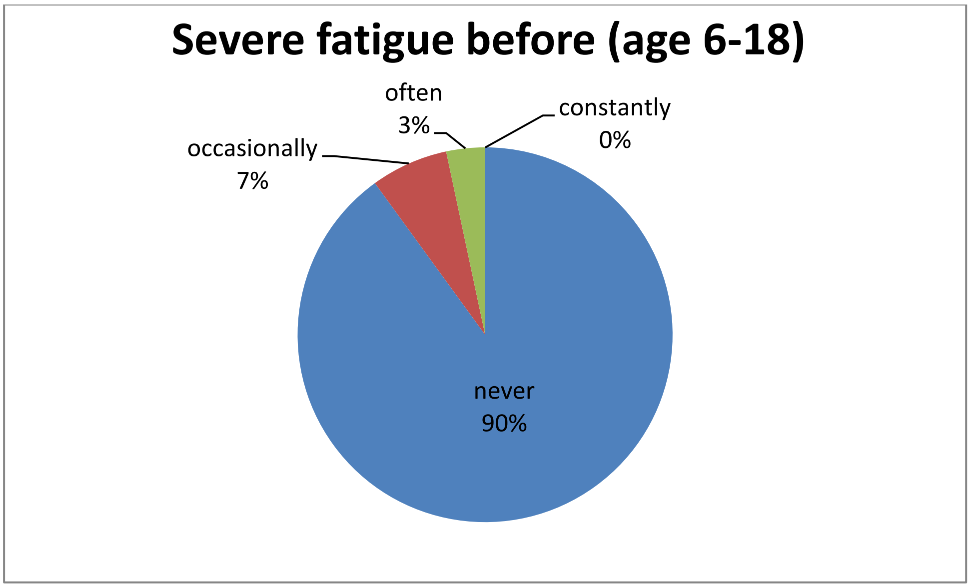

Skin irritation after (age 6-18)
never
23%
constantly
29%
occasionally
29%
often
19%

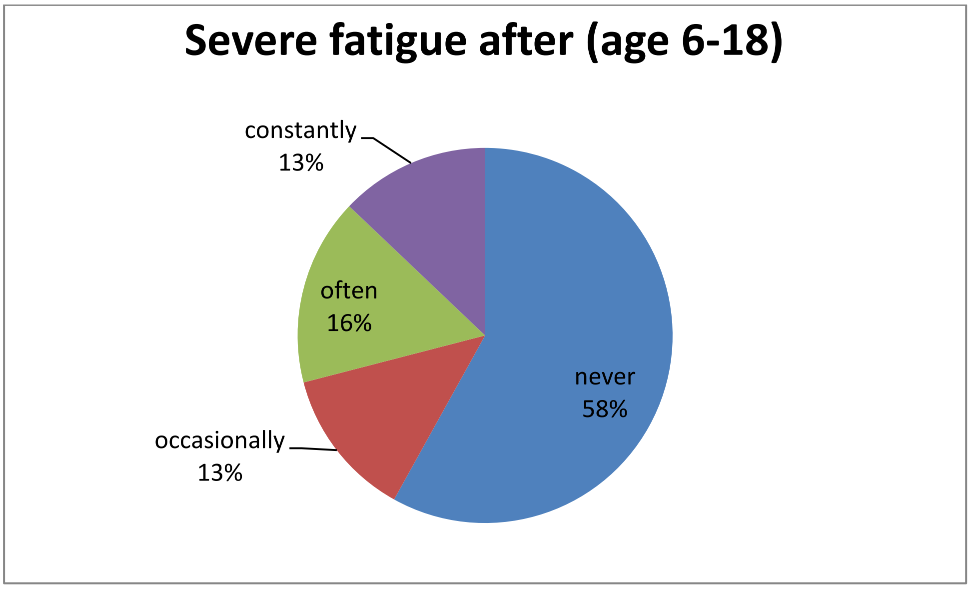

Rashes before (age 6-18)
often
0%
occasionally
10%
constantly
0%
never
90%

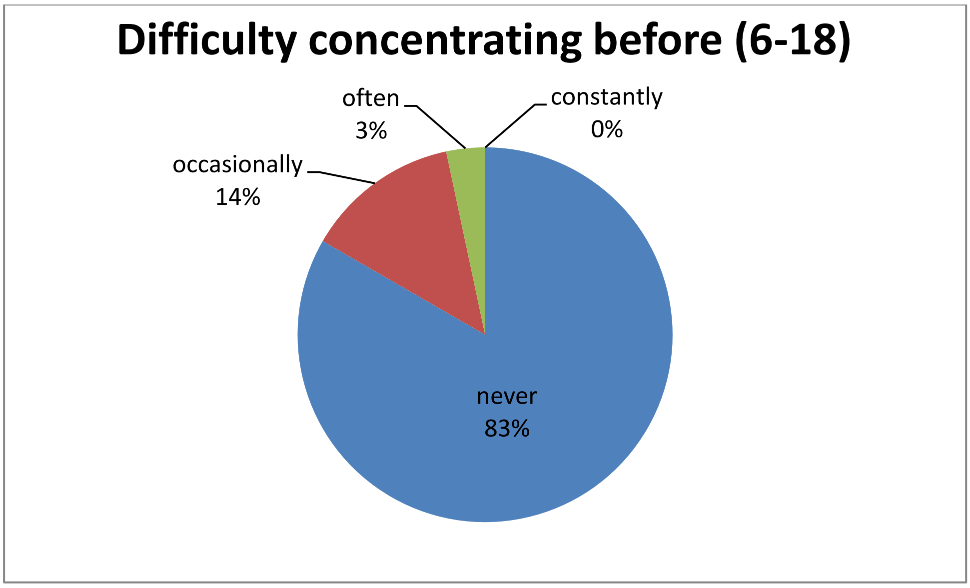

Rashes after (age 6-18)
constantly
16%
never
42%
often
16%
occasionally
26%

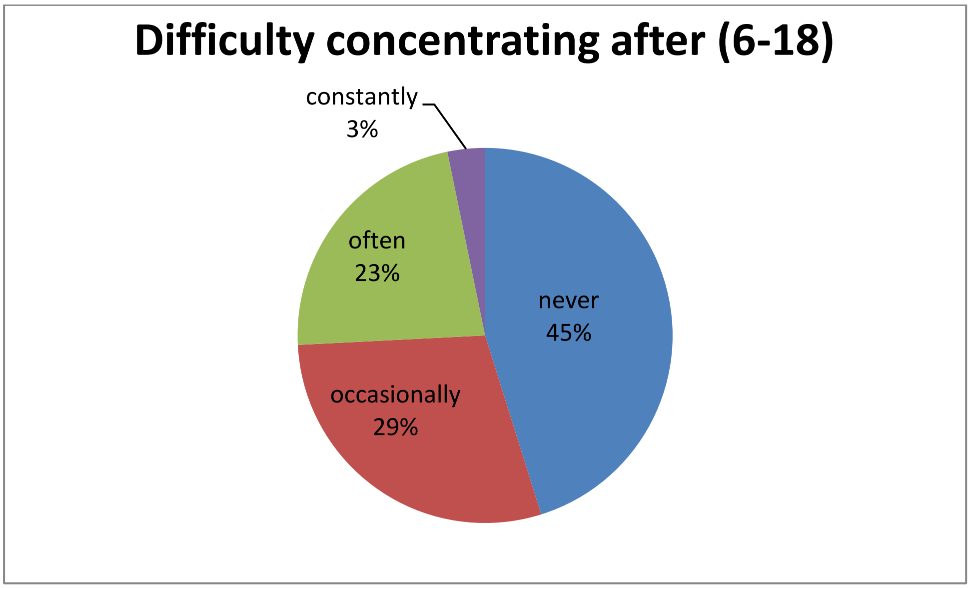

Dizzyness before (age 6-18)
often
3%
constantly
0%
occasionally
7%
never
90%

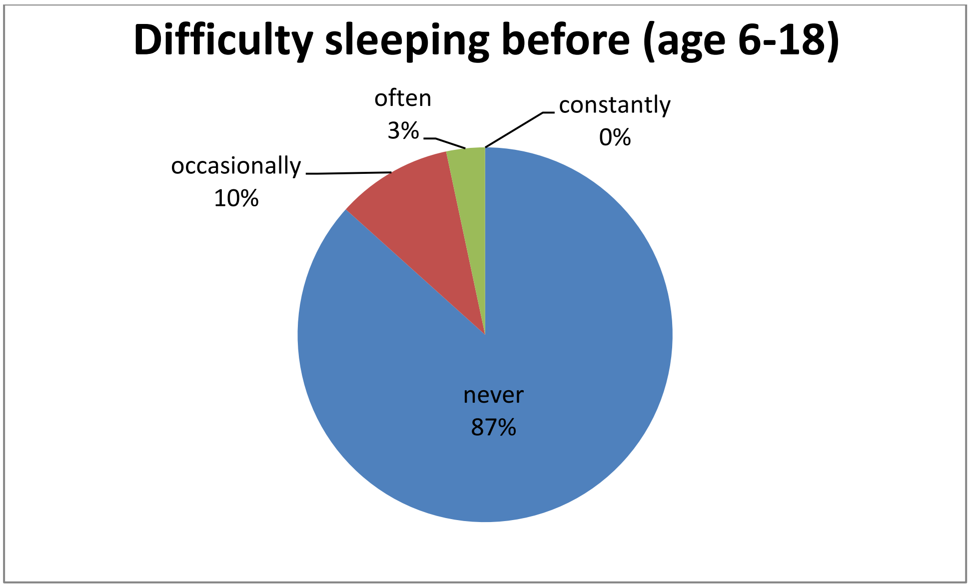

Dizzyness after (age 6-18)
constantly
0%
often
19%
never
39%
occasionally
42%

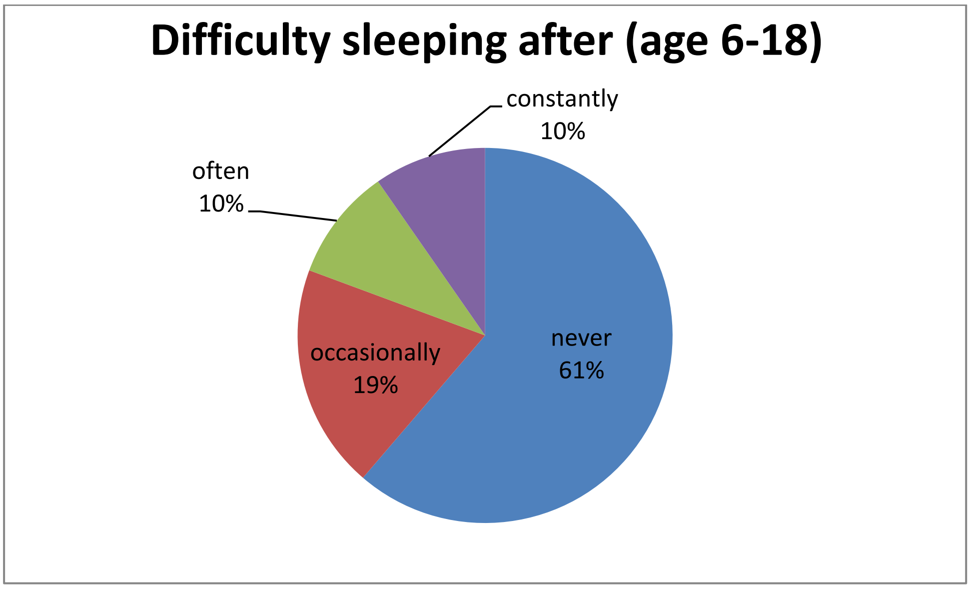

Severe fatigue before (age 6-18)
often
3%
constantly
0%
occasionally
7%
never
90%

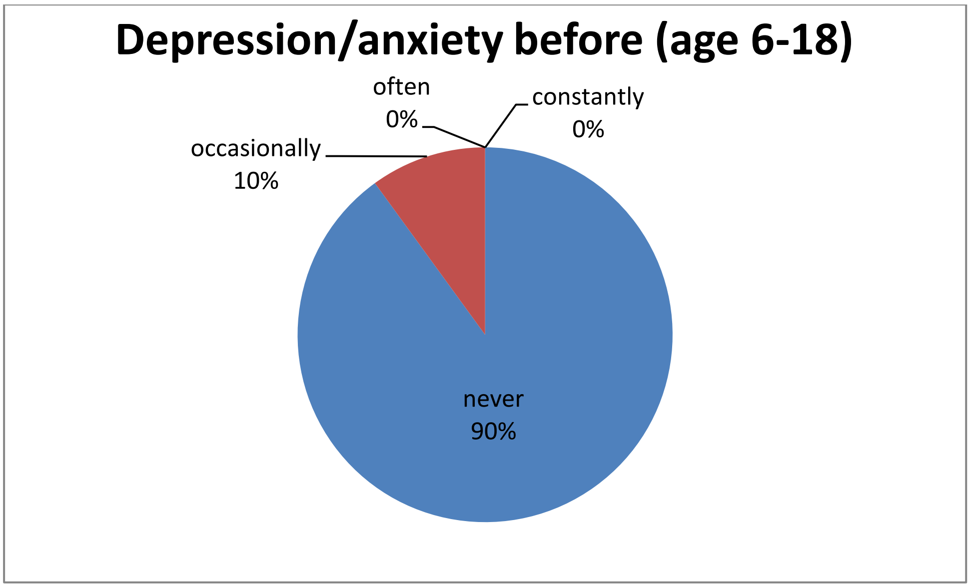

Severe fatigue after (age 6-18)
constantly
13%
often
16%
never
58%
occasionally
13%

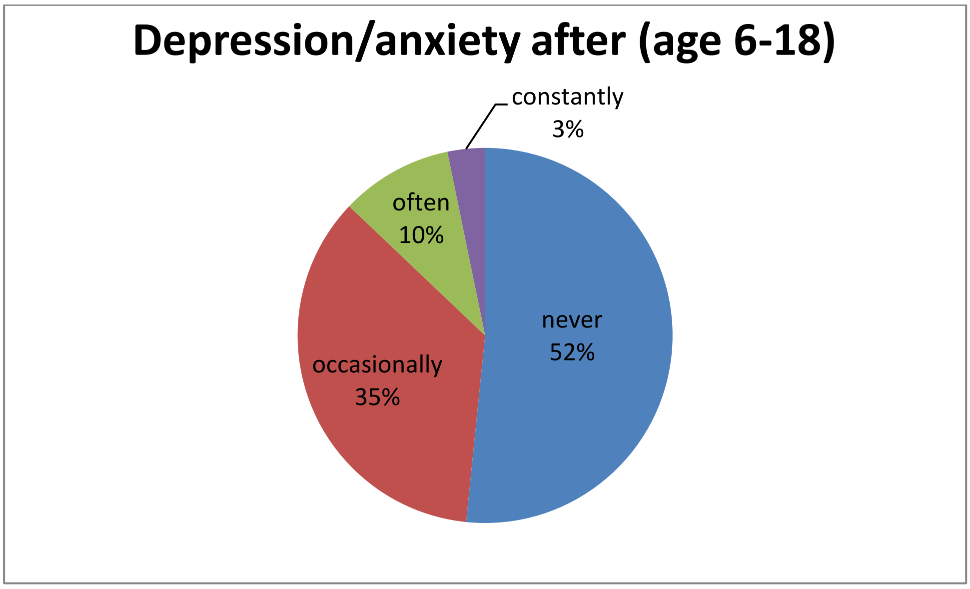

Difficulty concentrating before (6-18)
often
3%
constantly
0%
occasionally
14%
never
83%

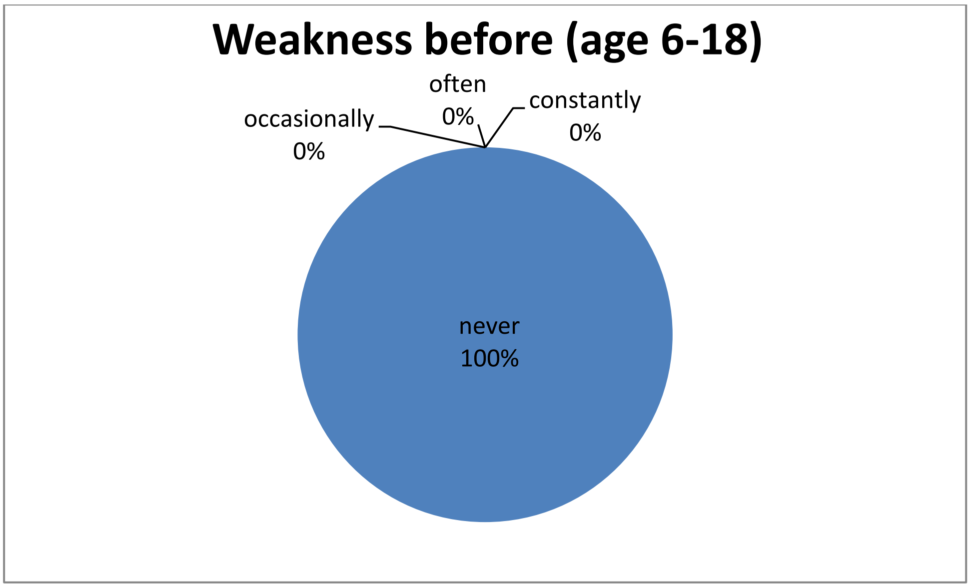

Difficulty concentrating after (6-18)
constantly
3%
often
23%
never
45%
occasionally
29%

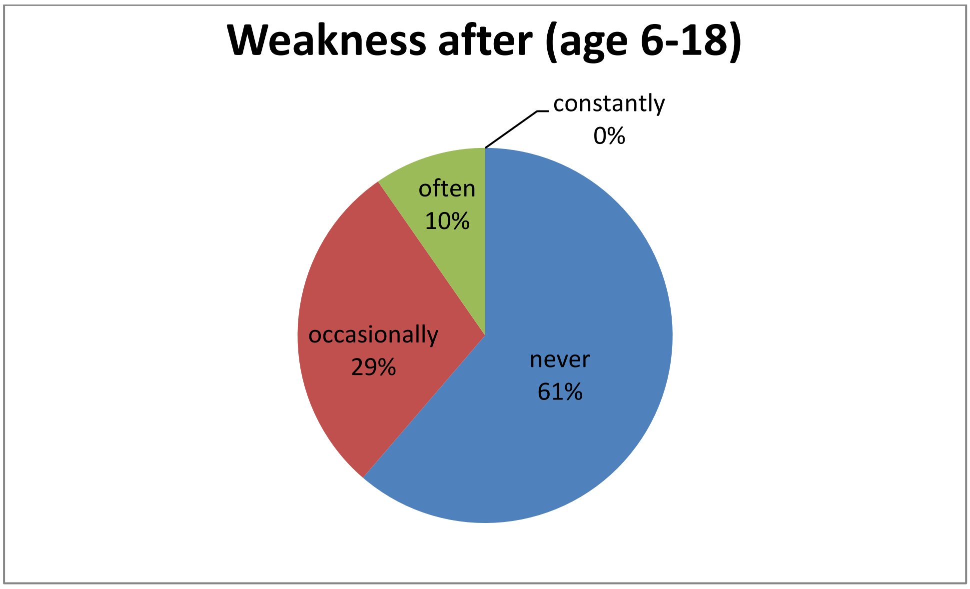

Difficulty sleeping before (age 6-18)
often
3%
constantly
0%
occasionally
10%
never
87%

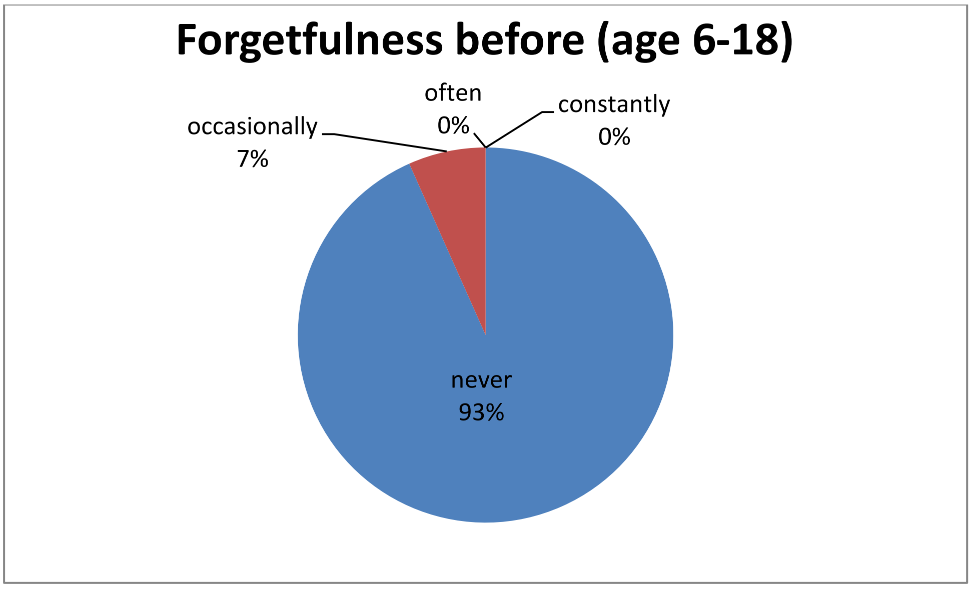

Difficulty sleeping after (age 6-18)
constantly
10%
often
10%
occasionally
19%
never
61%

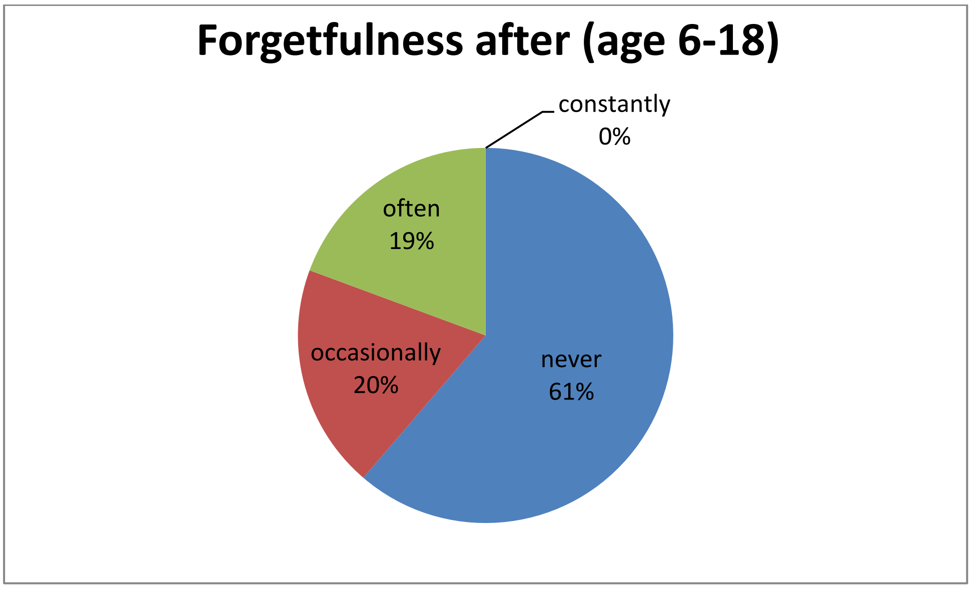

Depression/anxiety before (age 6-18)
often
0%
constantly
0%
occasionally
10%
never
90%

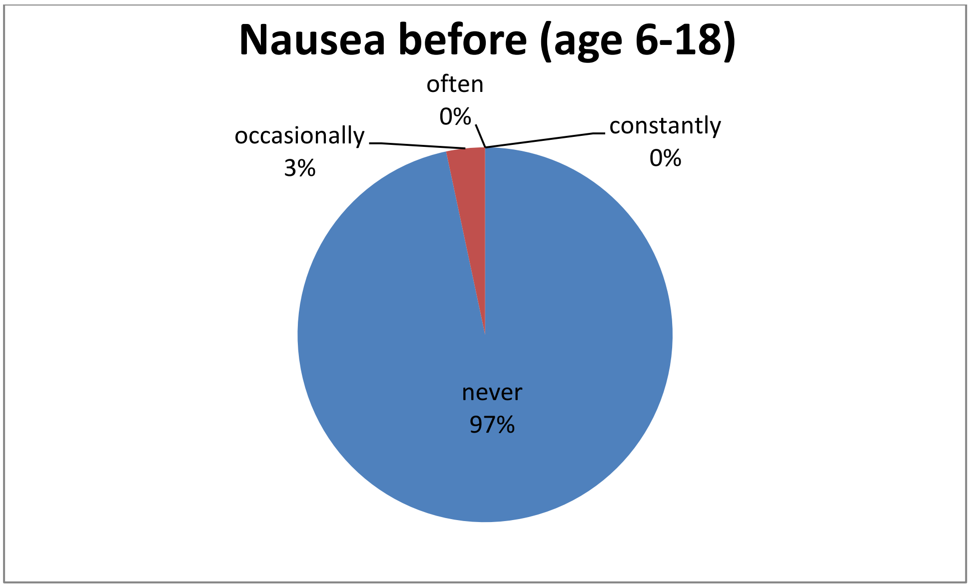

Depression/anxiety after (age 6-18)
constantly
3%
often
10%
never
52%
occasionally
35%

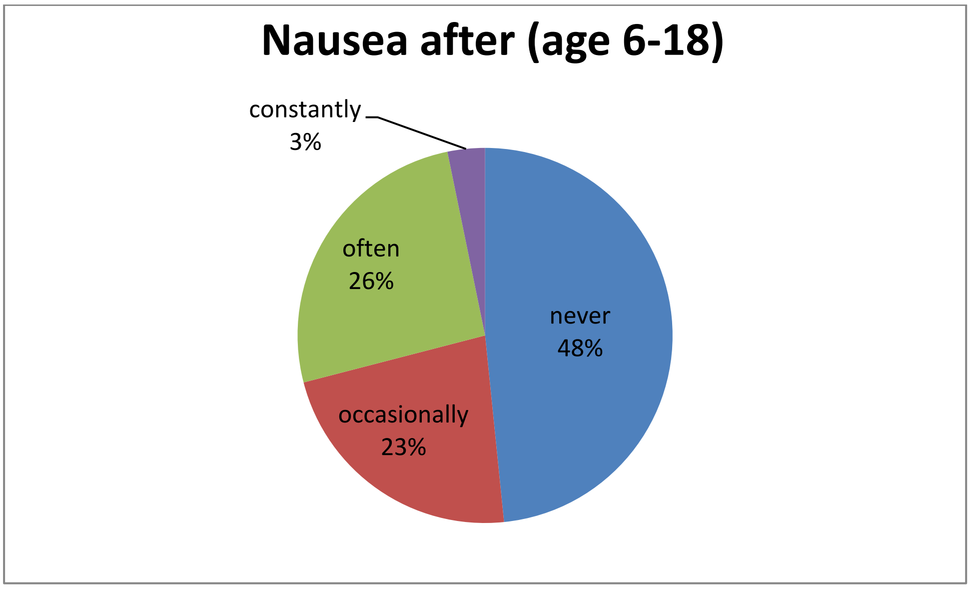

Weakness before (age 6-18)
often
0%
constantly
0%
occasionally
0%
never
100%

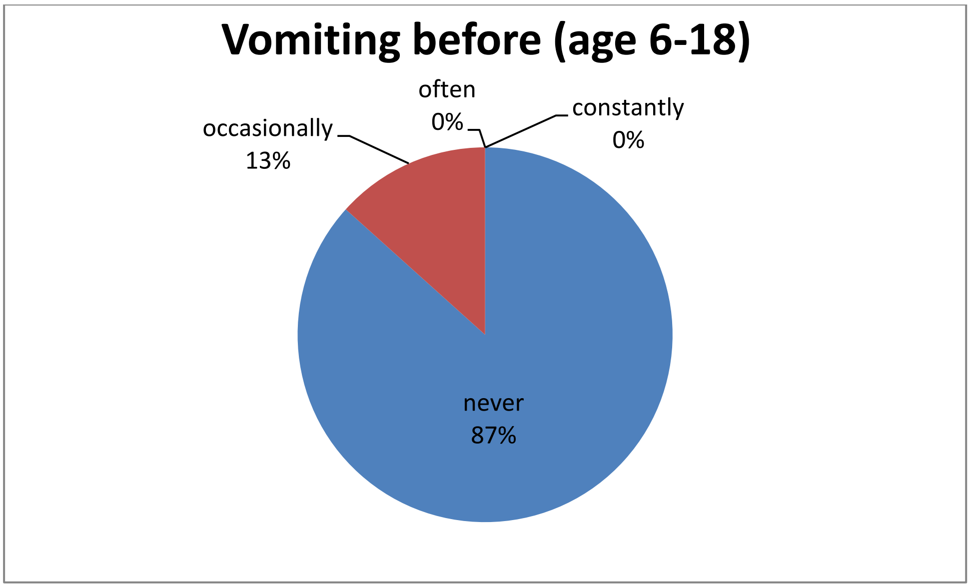

Weakness after (age 6-18)
constantly
0%
often
10%
occasionally
29%
never
61%

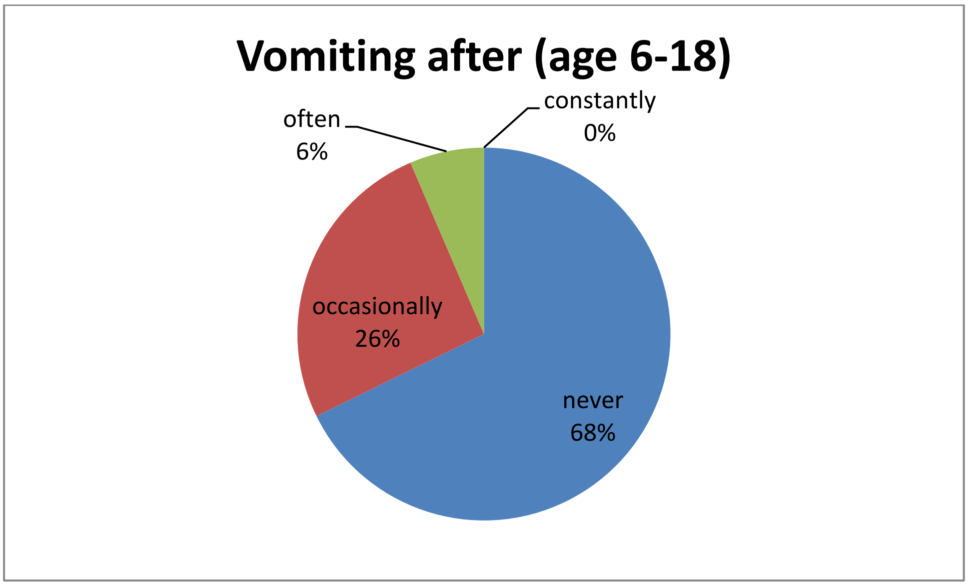

Forgetfulness before (age 6-18)
often
0%
constantly
0%
occasionally
7%
never
93%

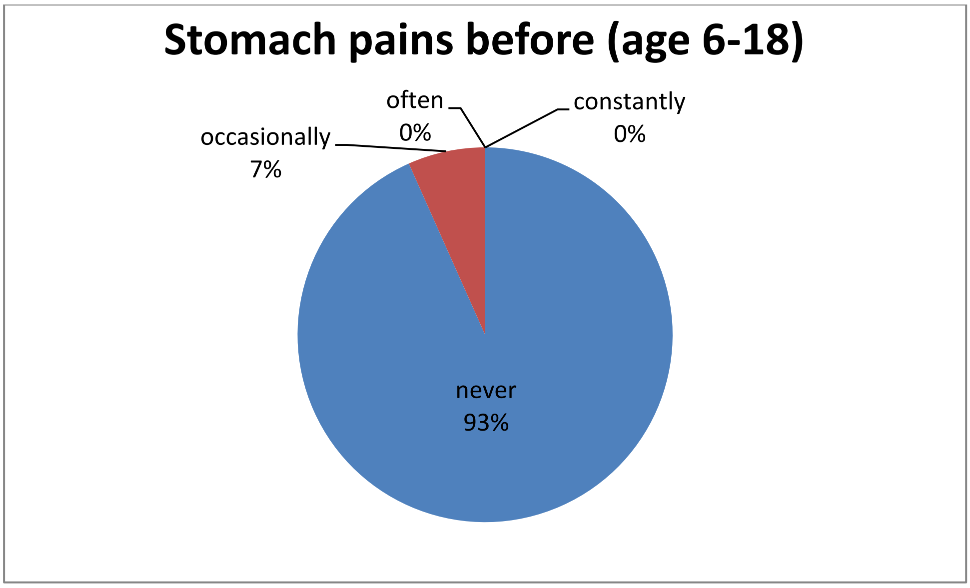

Forgetfulness after (age 6-18)
constantly
0%
often
19%
occasionally
20%
never
61%

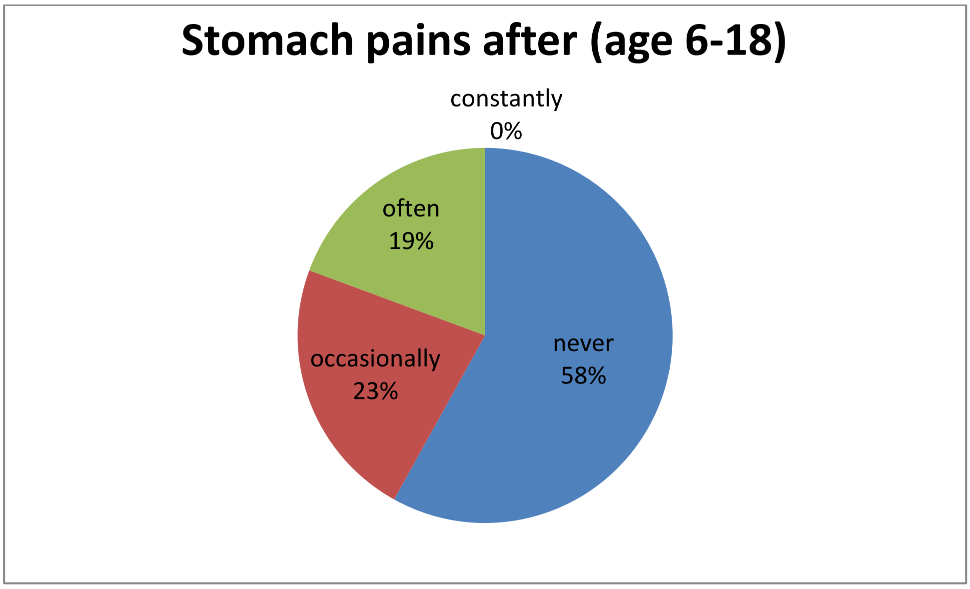

Nausea before (age 6-18)
often
0%
occasionally
3%
constantly
0%
never
97%

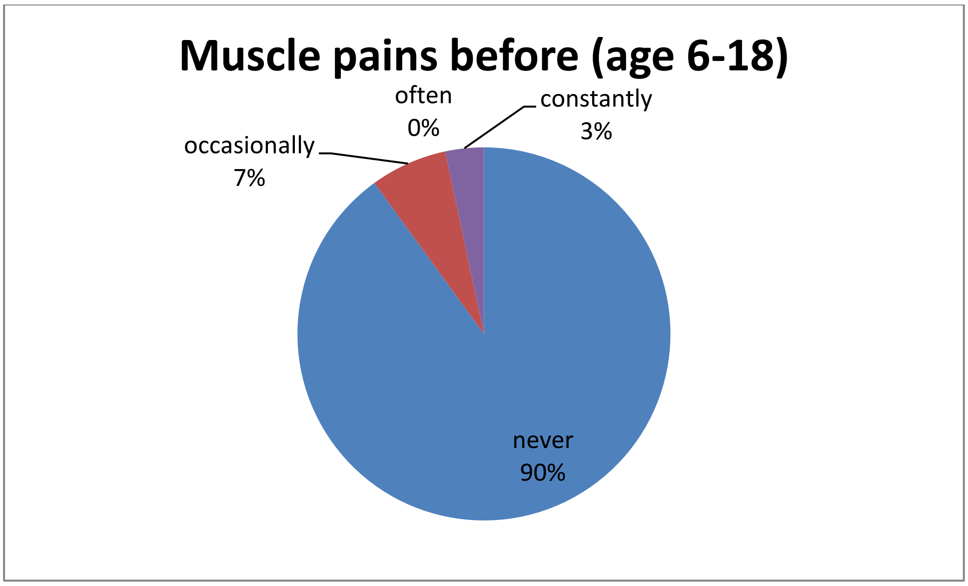

Nausea after (age 6-18)
constantly
3%
often
26%
never
48%
occasionally
23%

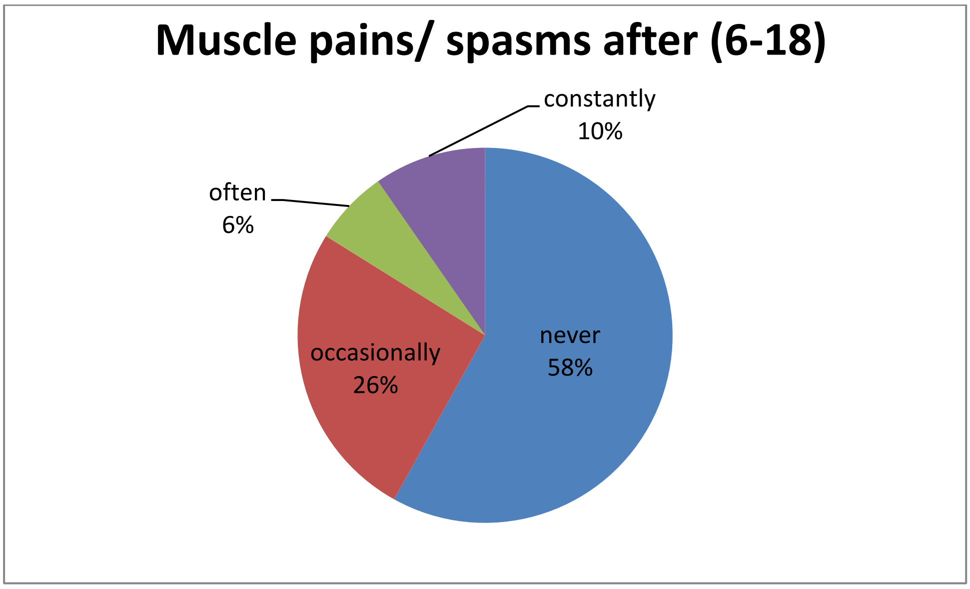

Vomiting before (age 6-18)
often
0%
constantly
0%
occasionally
13%
never
87%

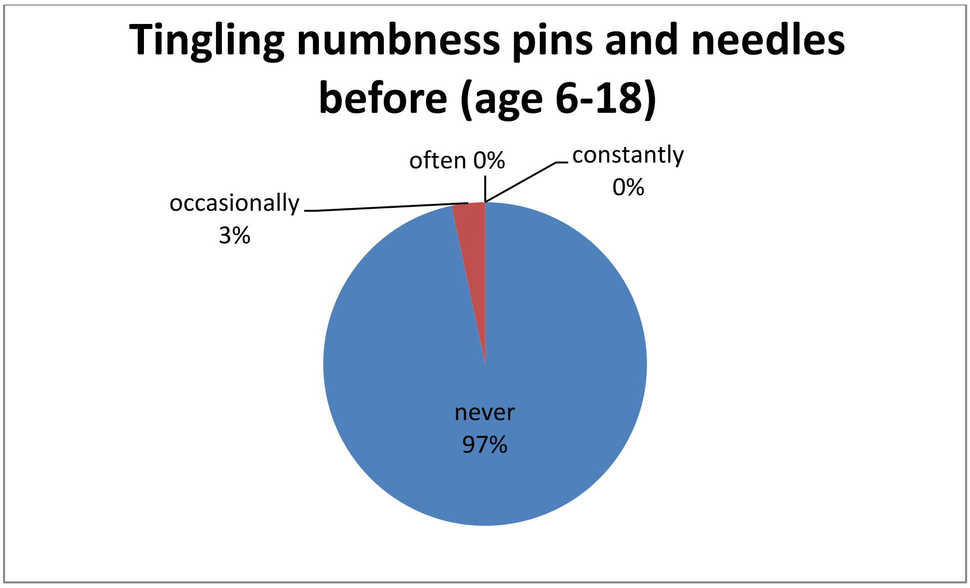

Vomiting after (age 6-18)
constantly
0%
often
6%
occasionally
26%
never
68%

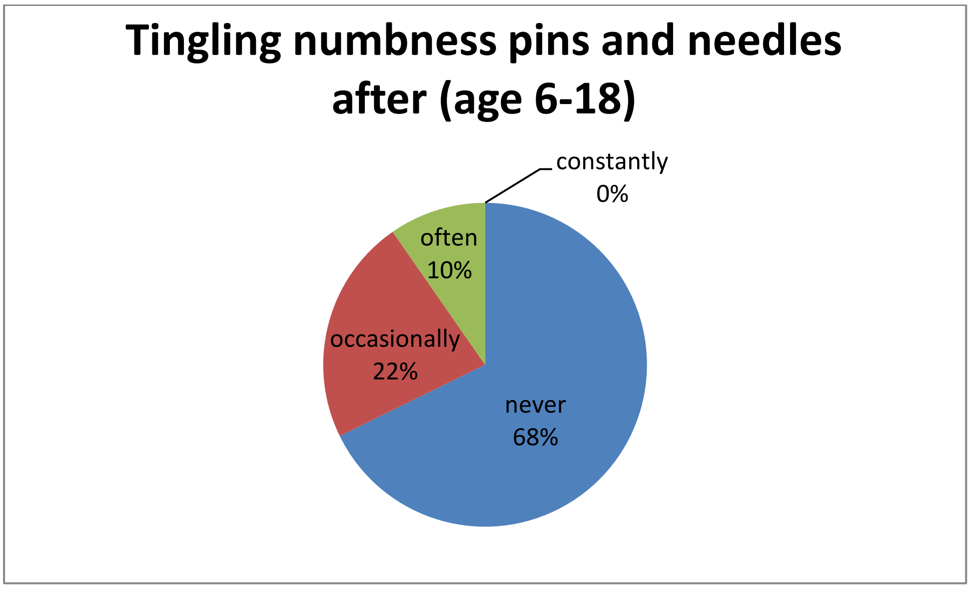

Stomach pains before (age 6-18)
often
0%
constantly
0%
occasionally
7%
never
93%

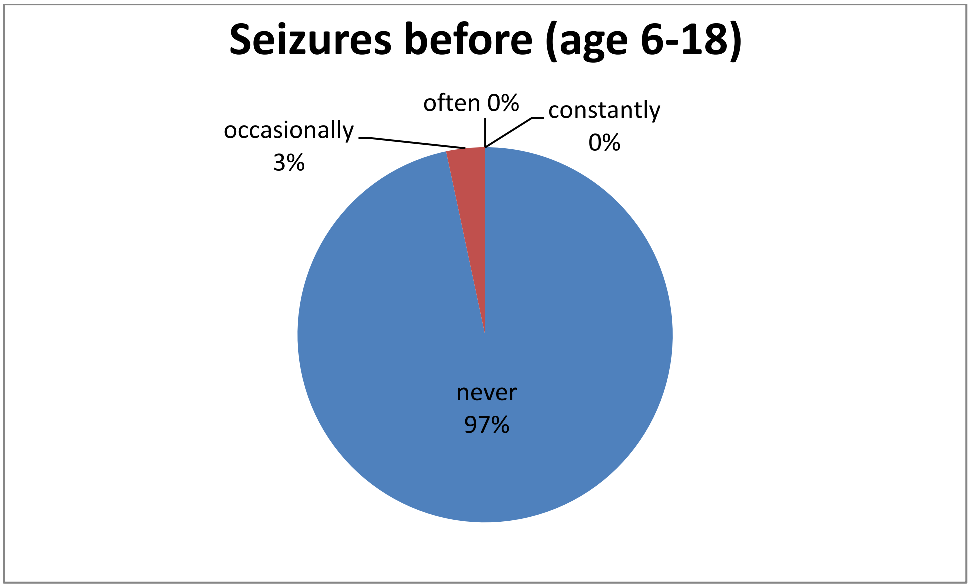

Stomach pains after (age 6-18)
constantly
0%
often
19%
occasionally
23%
never
58%

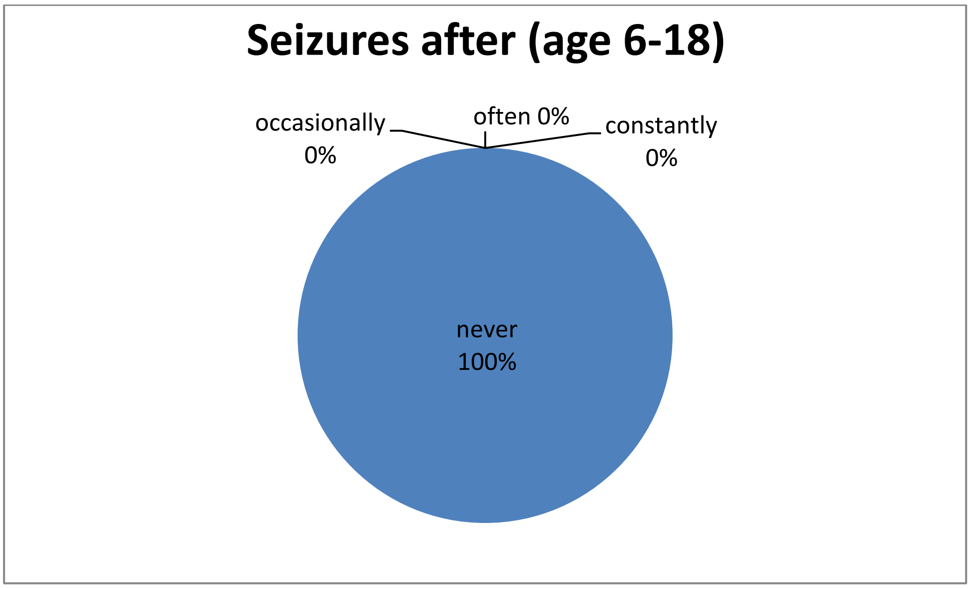

Muscle pains before (age 6-18)
often
0%
constantly
3%
occasionally
7%
never
90%

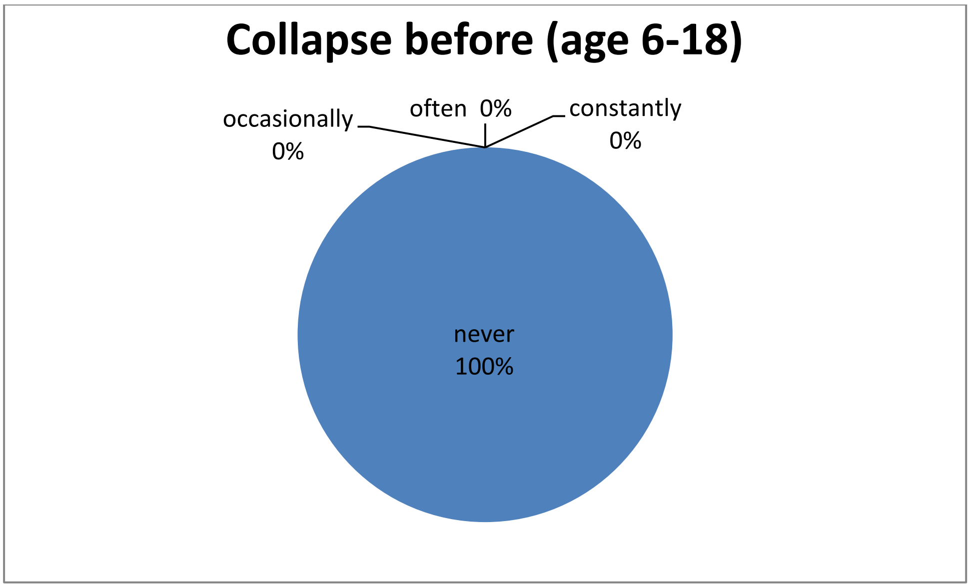

Muscle pains/ spasms after (6-18)
constantly
10%
often
6%
occasionally
26%
never
58%

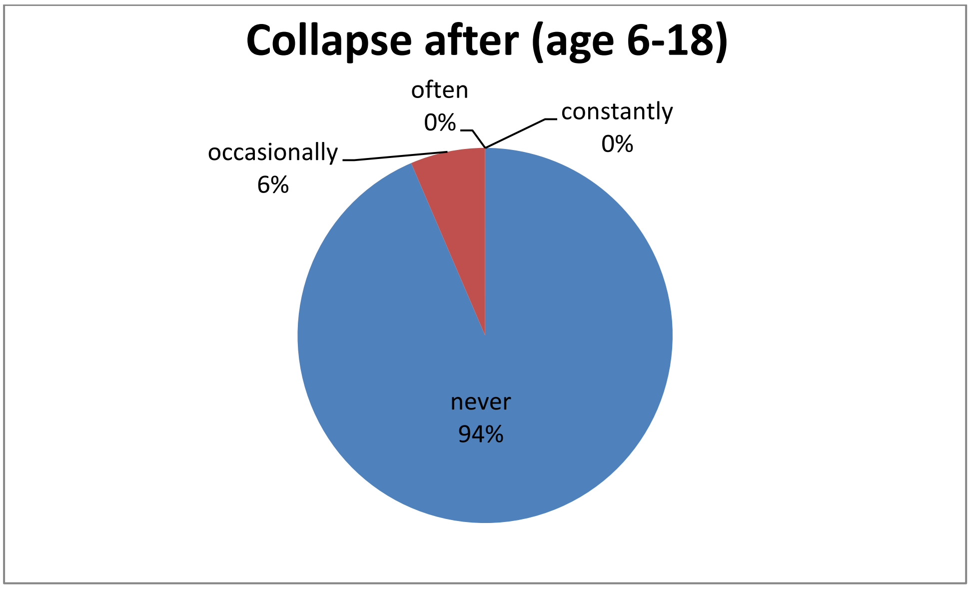

Tingling numbness pins and needles before (age 6-18)
often 0%
constantly 0%
occasionally 3%
never 97%

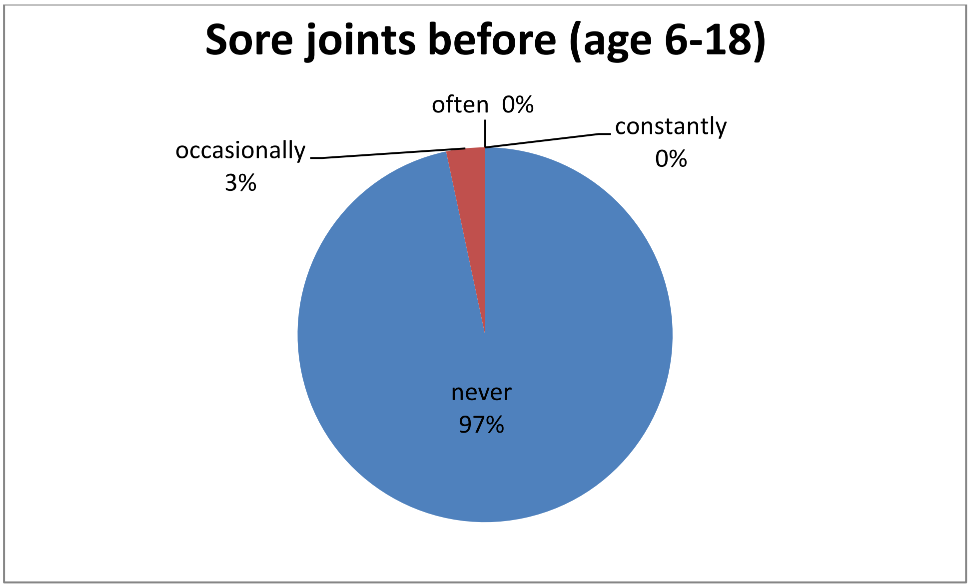

Tingling numbness pins and needles after (age 6-18)
constantly 0%
often 10%
occasionally 22%
never 68%

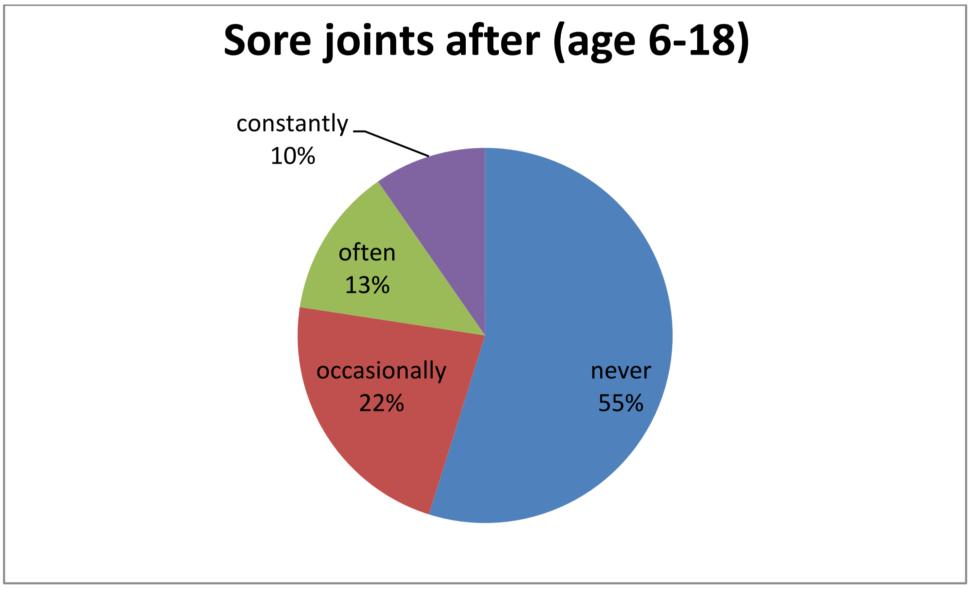

Seizures before (age 6-18)
often 0%
constantly 0%
occasionally 3%
never 97%


Seizures after (age 6-18)
occasionally 0%
often 0%
constantly 0%
never 100%

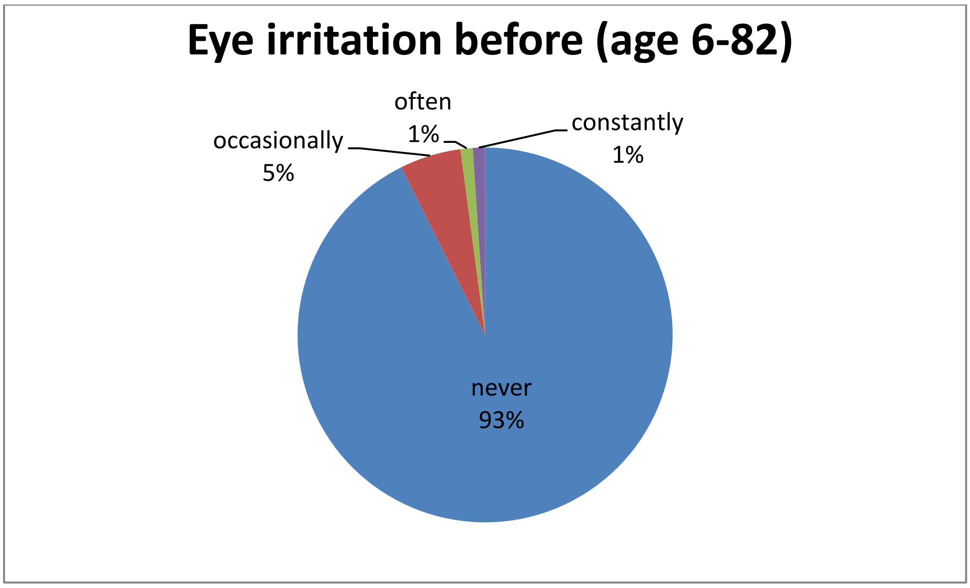

Collapse before (age 6-18)
occasionally 0%
often 0%
constantly 0%
never 100%

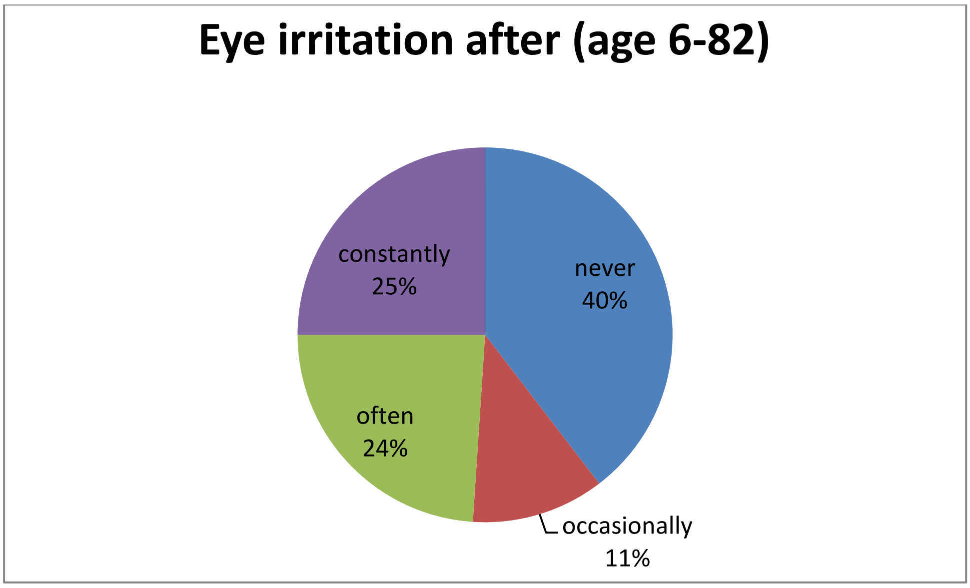

Collapse after (age 6-18)
often 0%
constantly 0%
occasionally 6%
never 94%

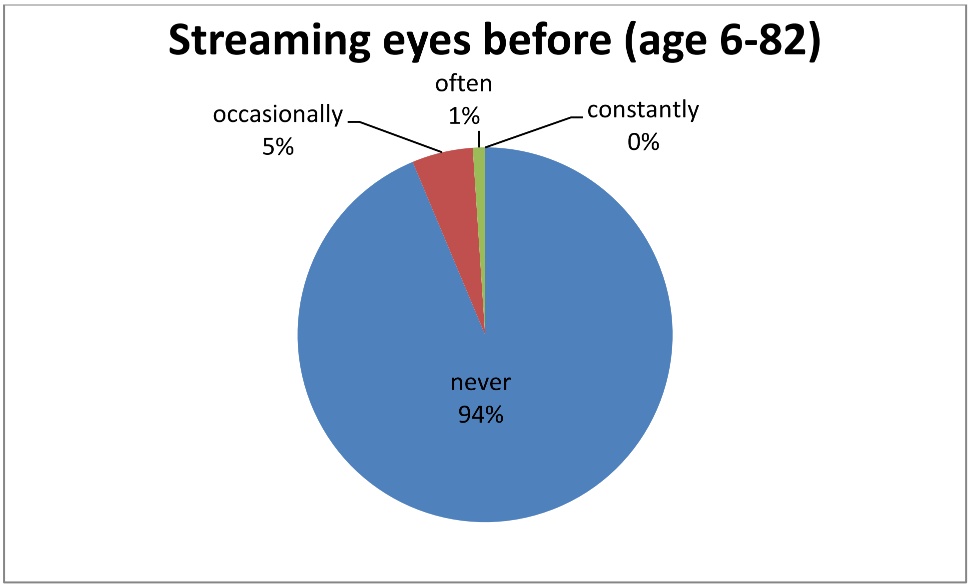

Sore joints before (age 6-18)
often 0%
constantly 0%
occasionally 3%
never 97%

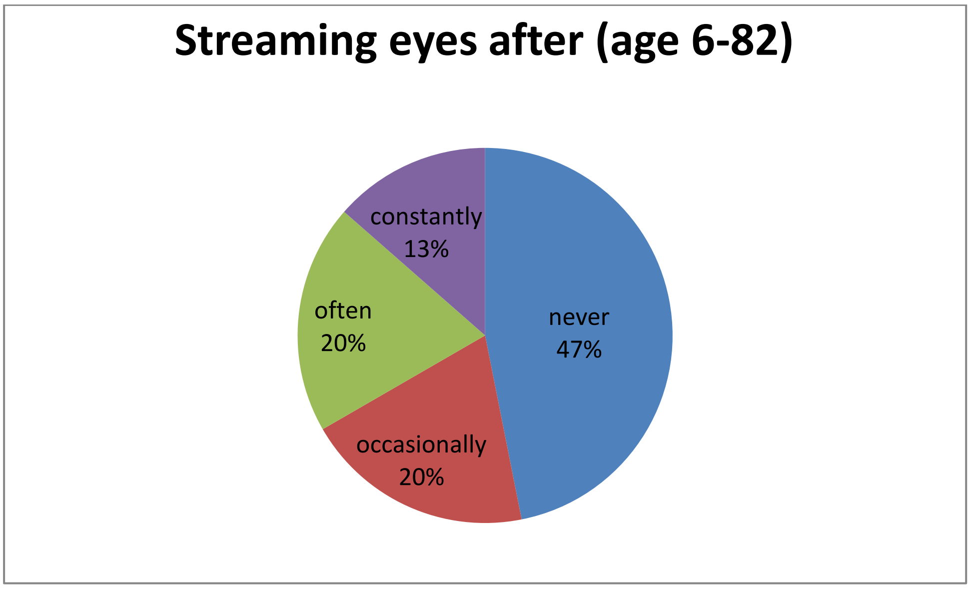

Sore joints after (age 6-18)
constantly 10%
often 13%
occasionally 22%
never 55%

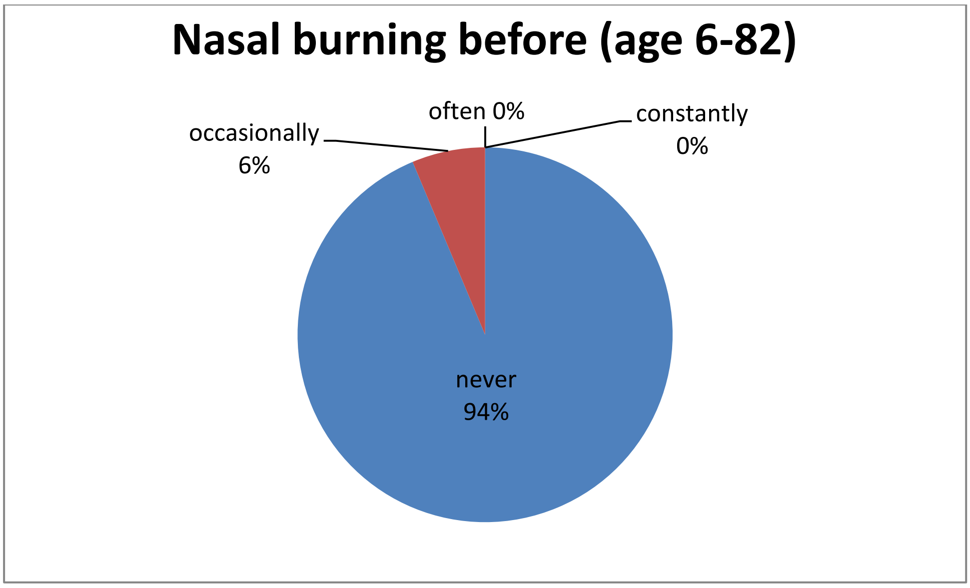
Age 6-82 Symptoms reported before and after Coal Seam Gas development – Pie Charts

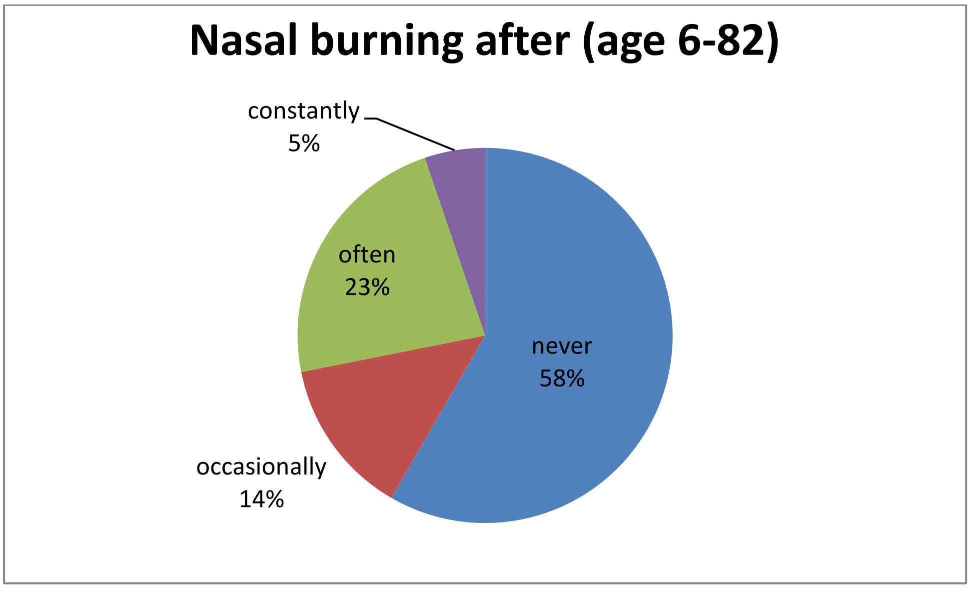


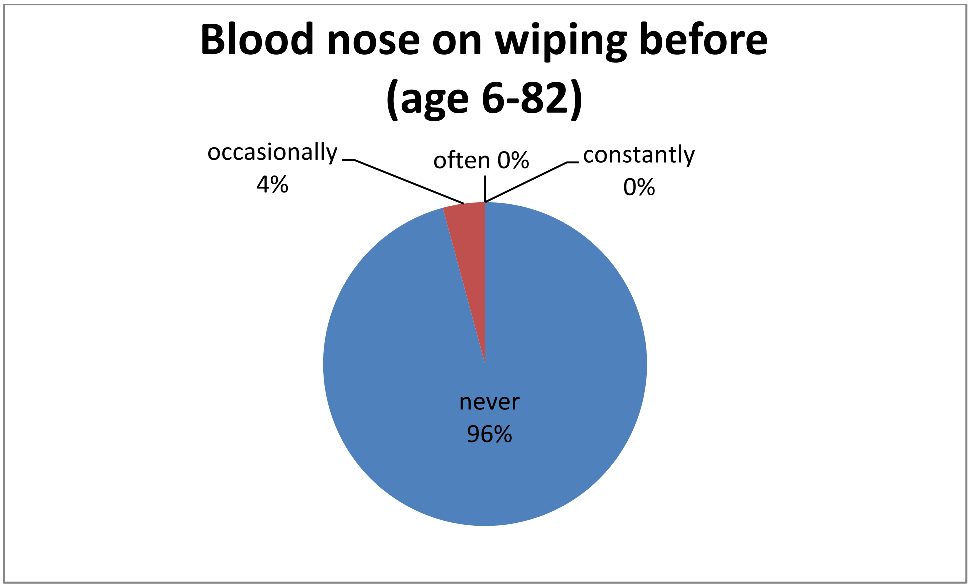


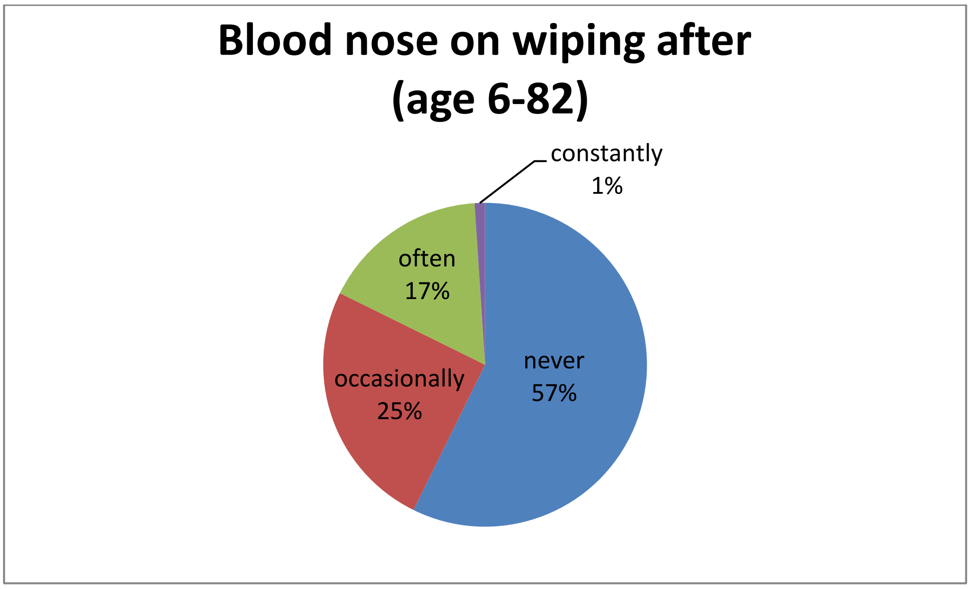

Streaming eyes before (age 6-82)
occasionally
5%
often
1%
constantly
0%
never
94%

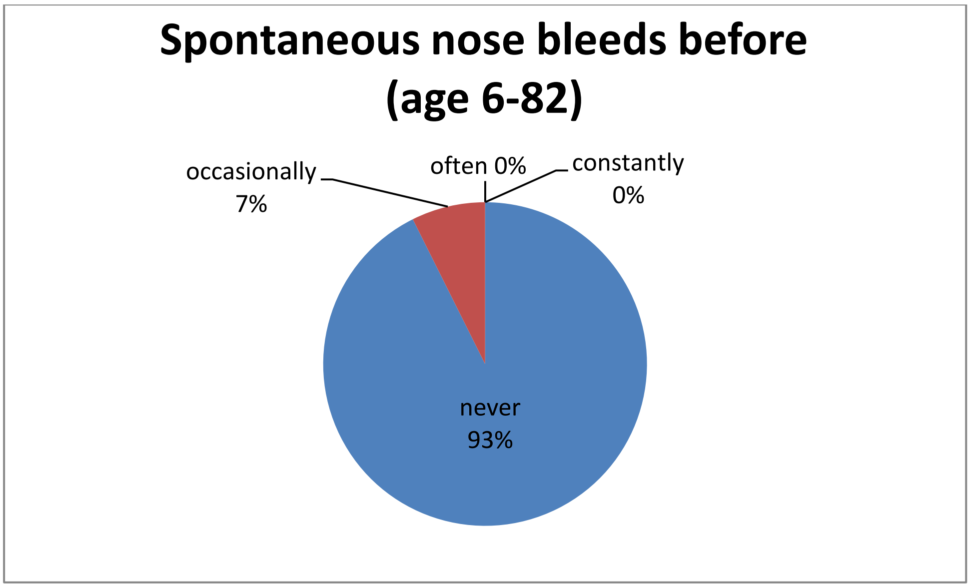

Streaming eyes after (age 6-82)
constantly
13%
often
20%
never
47%
occasionally
20%

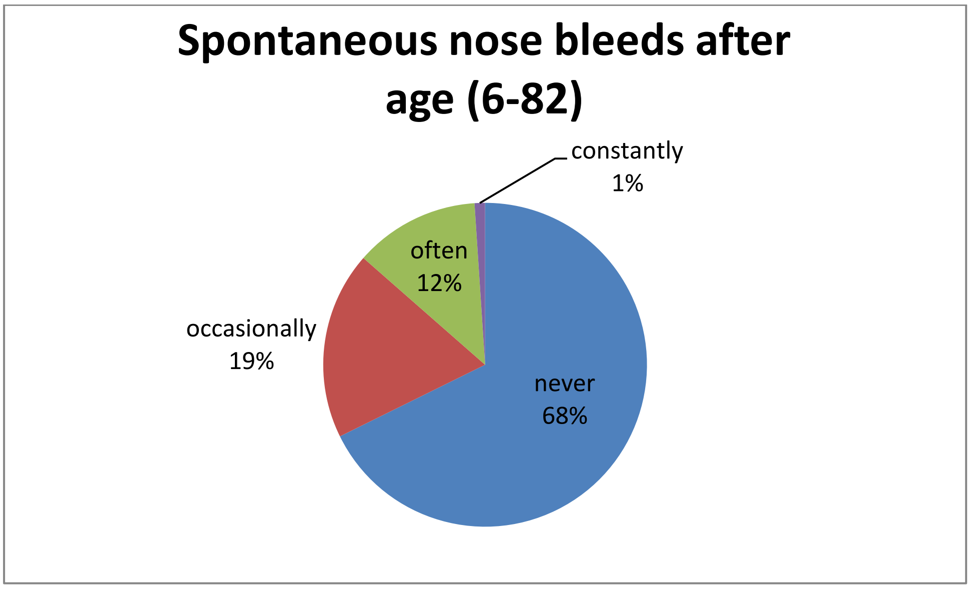

Nasal burning before (age 6-82)
occasionally
6%
often 0%
constantly
0%
never
94%

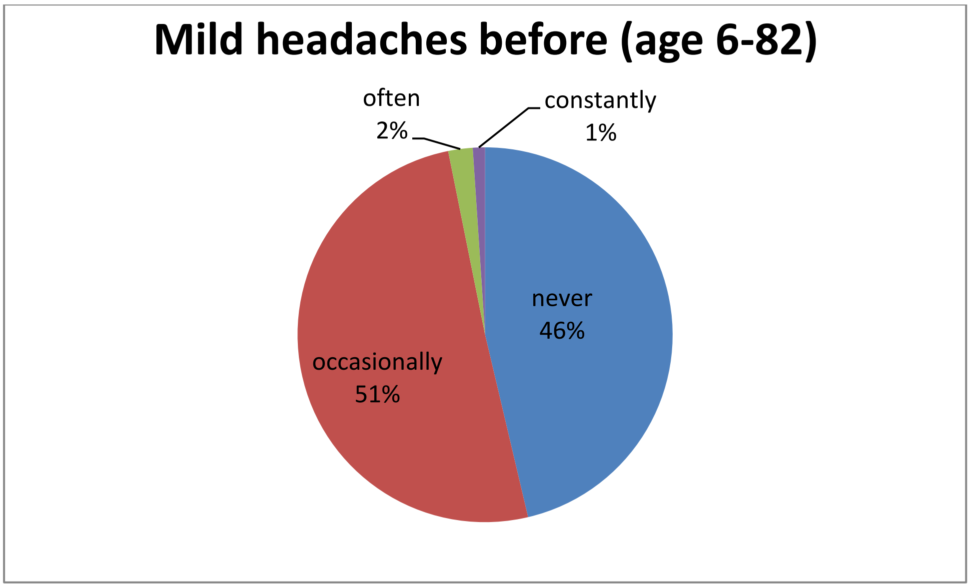

Nasal burning after (age 6-82)
constantly
5%
often
23%
never
58%
occasionally
14%

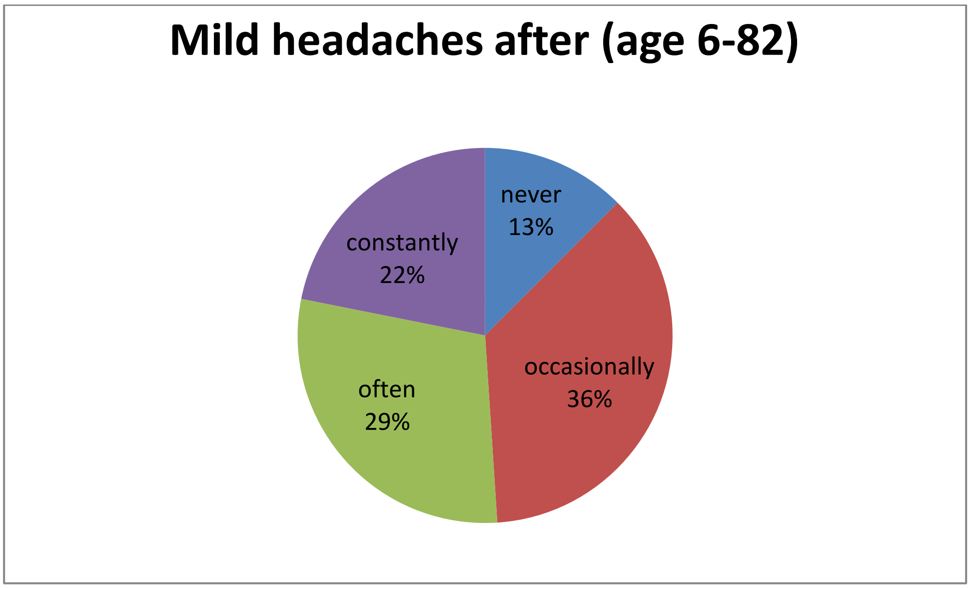

Blood nose on wiping before
(age 6-82)
occasionally
4%
often 0%
constantly
0%
never
96%

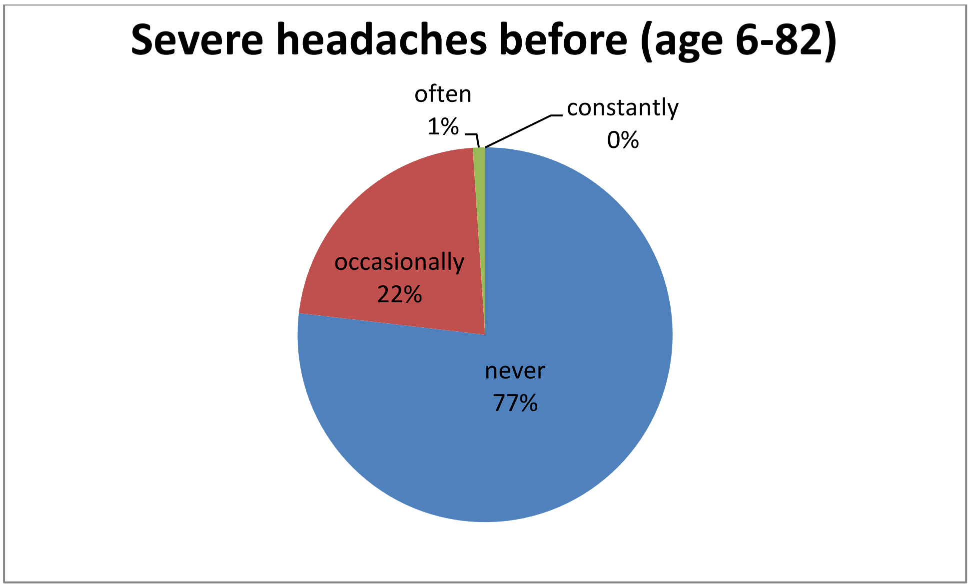

Blood nose on wiping after
(age 6-82)
constantly
1%
often
17%
occasionally
25%
never
57%

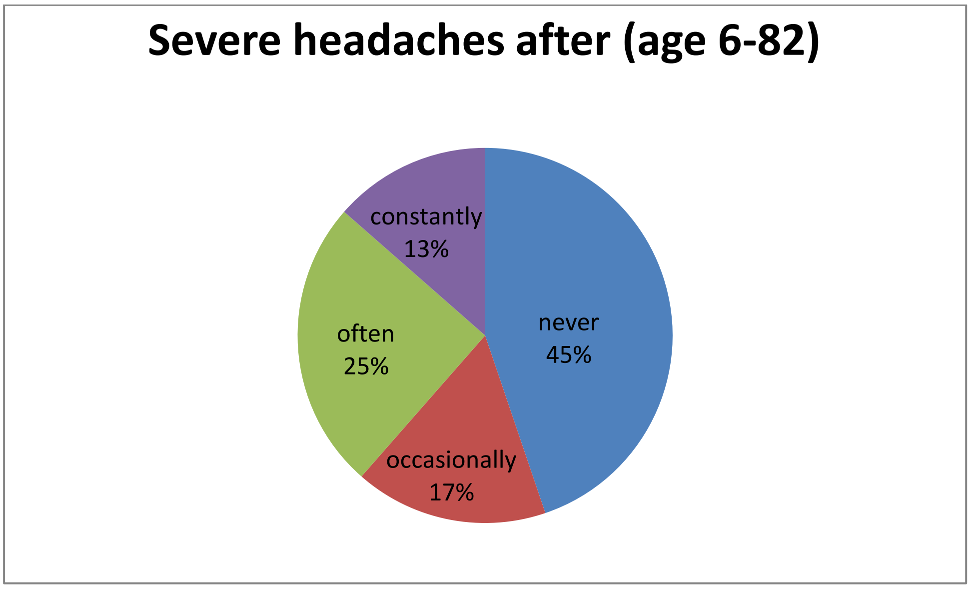

Spontaneous nose bleeds before (age 6-82)
occasionally 7%
often 0%
constantly 0%
never 93%

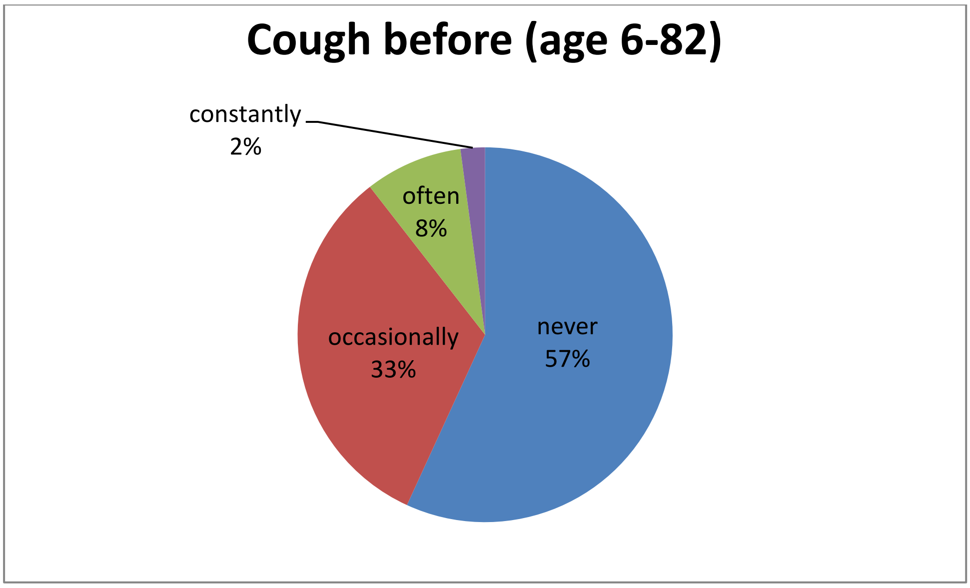

Spontaneous nose bleeds after age (6-82)
constantly 1%
often 12%
occasionally 19%
never 68%

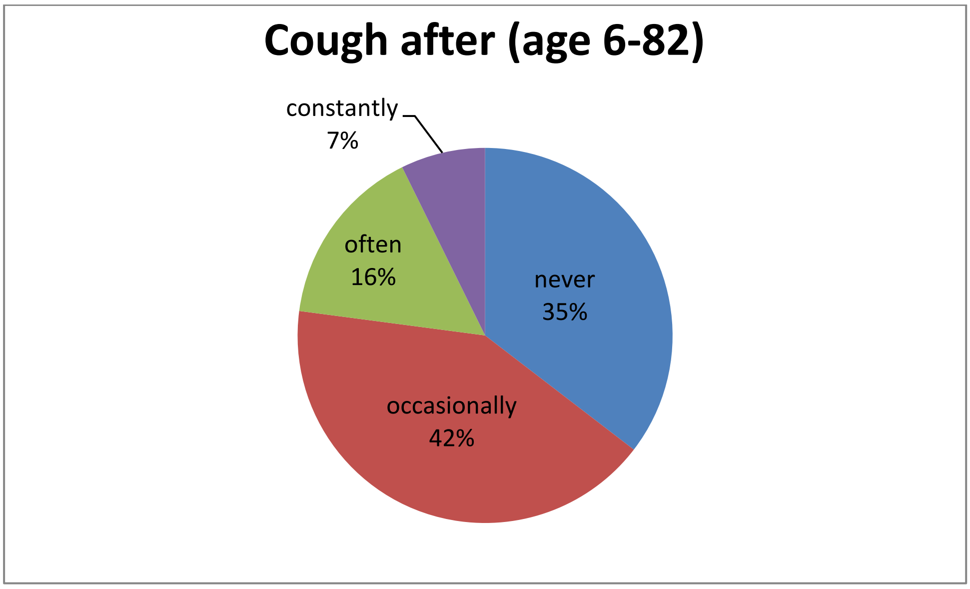

Mild headaches before (age 6-82)
often
2%
constantly
1%
never
46%
occasionally
51%

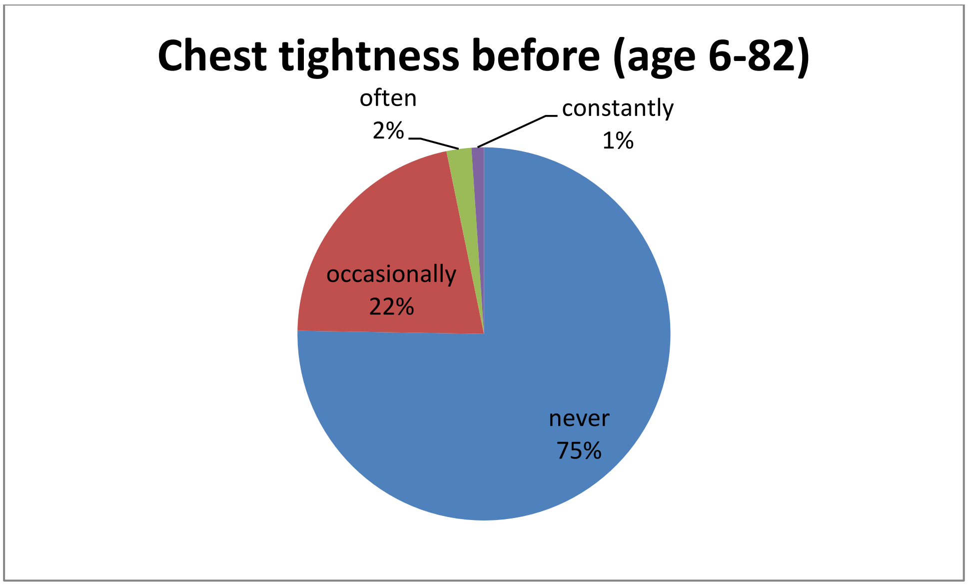

Mild headaches after (age 6-82)
never
13%
constantly
22%
occasionally
36%
often
29%

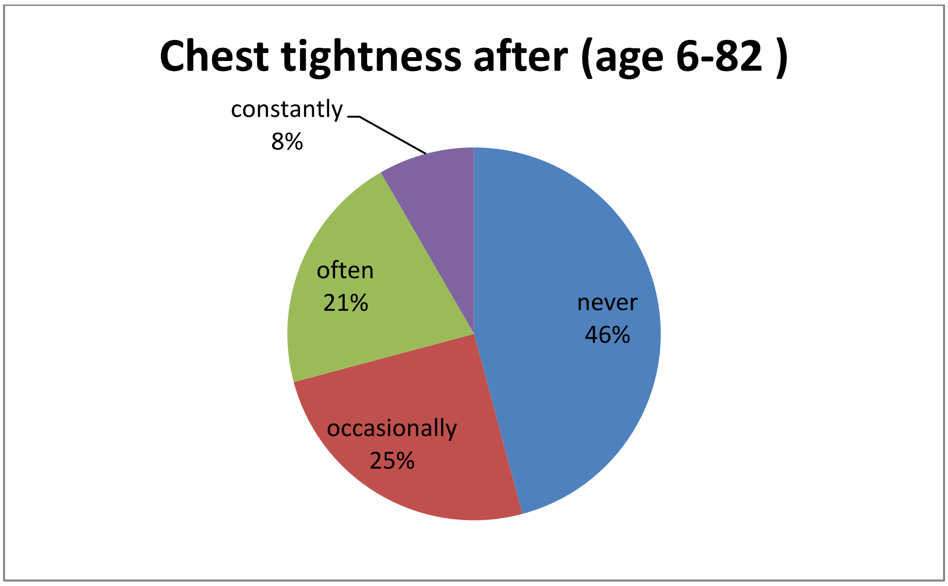

Severe headaches before (age 6-82)
often
1%
constantly
0%
occasionally
22%
never
77%

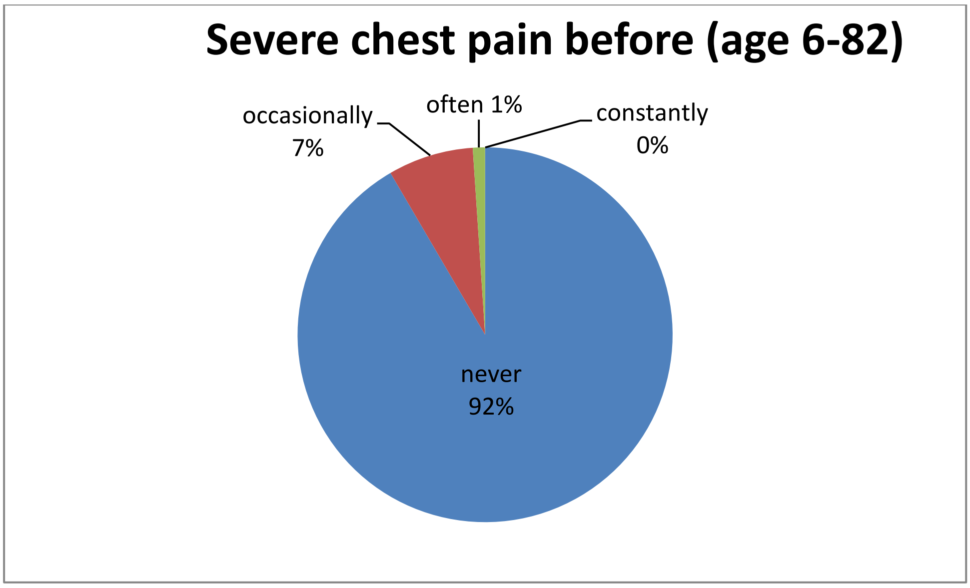

Severe headaches after (age 6-82)
constantly
13%
often
25%
never
45%
occasionally
17%

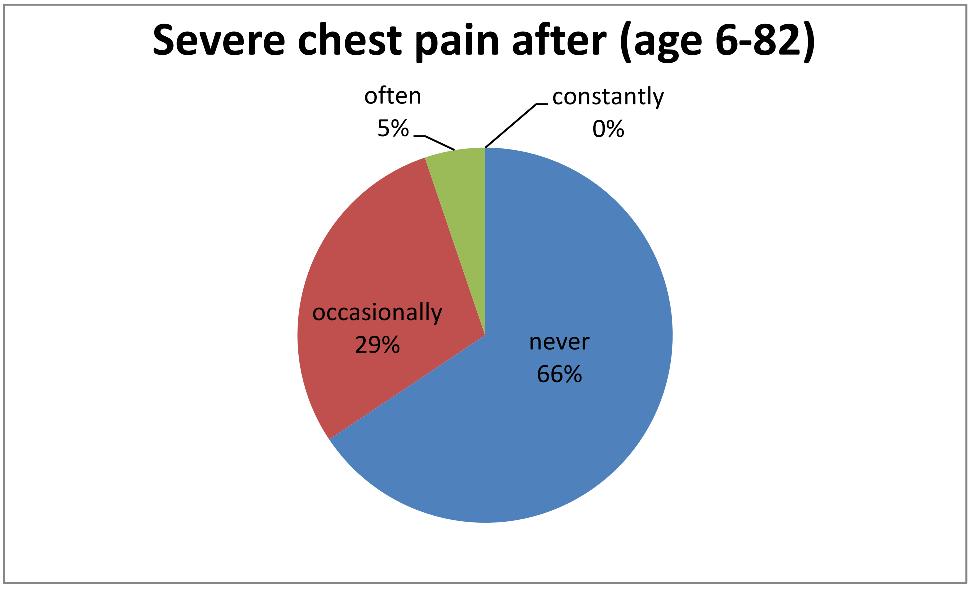

Cough before (age 6-82)
constantly
2%
often
8%
occasionally
33%
never
57%

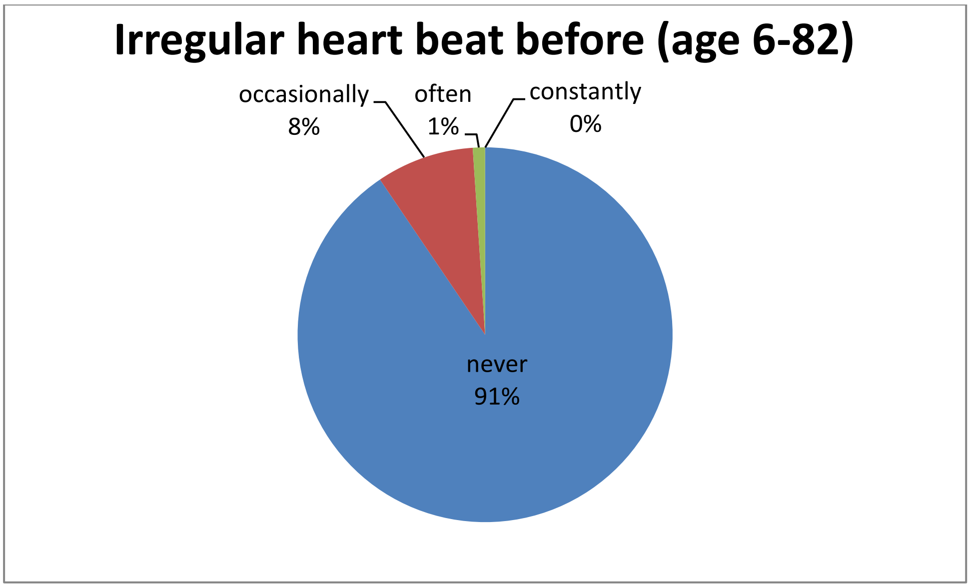

Cough after (age 6-82)
constantly
7%
often
16%
never
35%
occasionally
42%

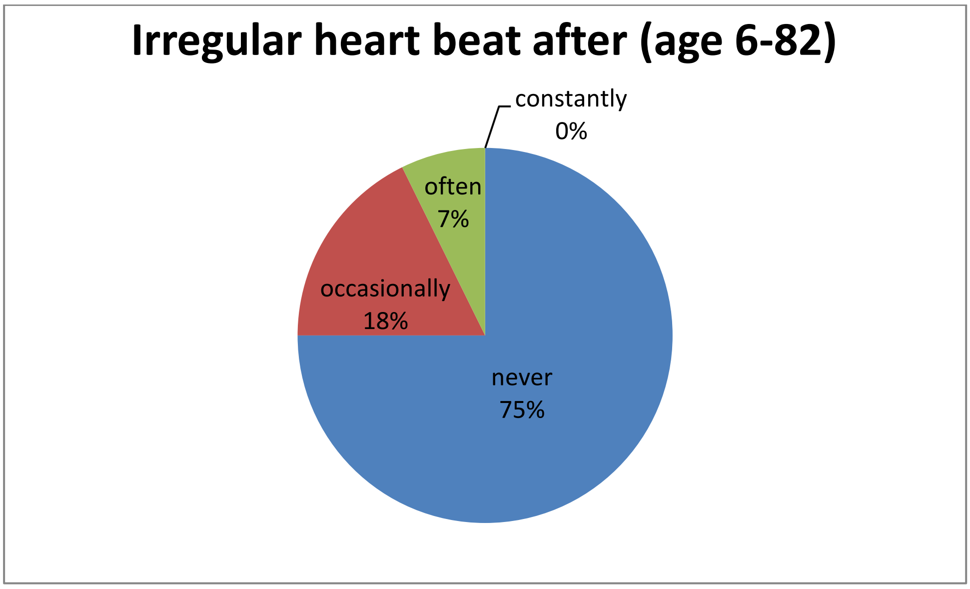

Chest tightness before (age 6-82)
often
2%
constantly
1%
occasionally
22%
never
75%

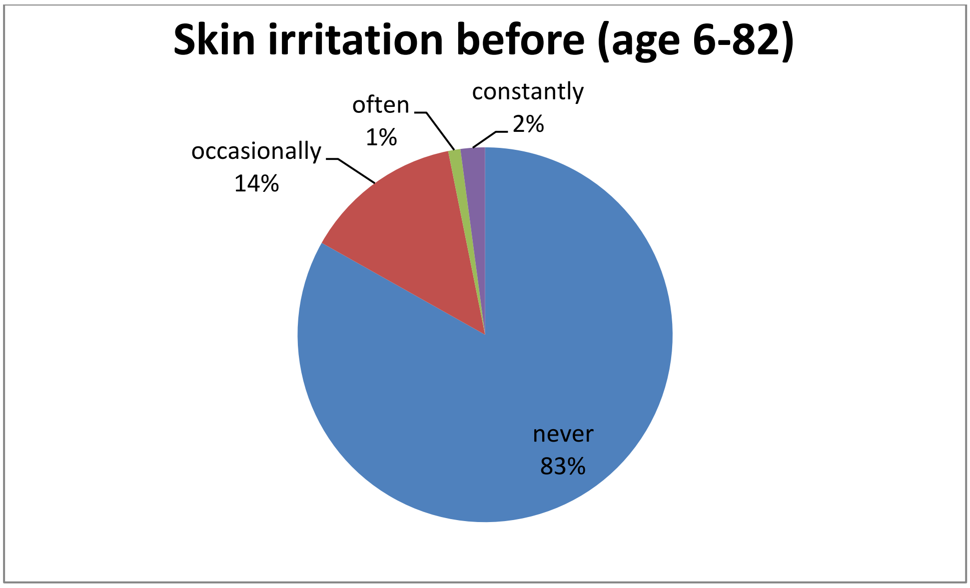

Chest tightness after (age 6-82)
constantly
8%
often
21%
never
46%
occasionally
25%

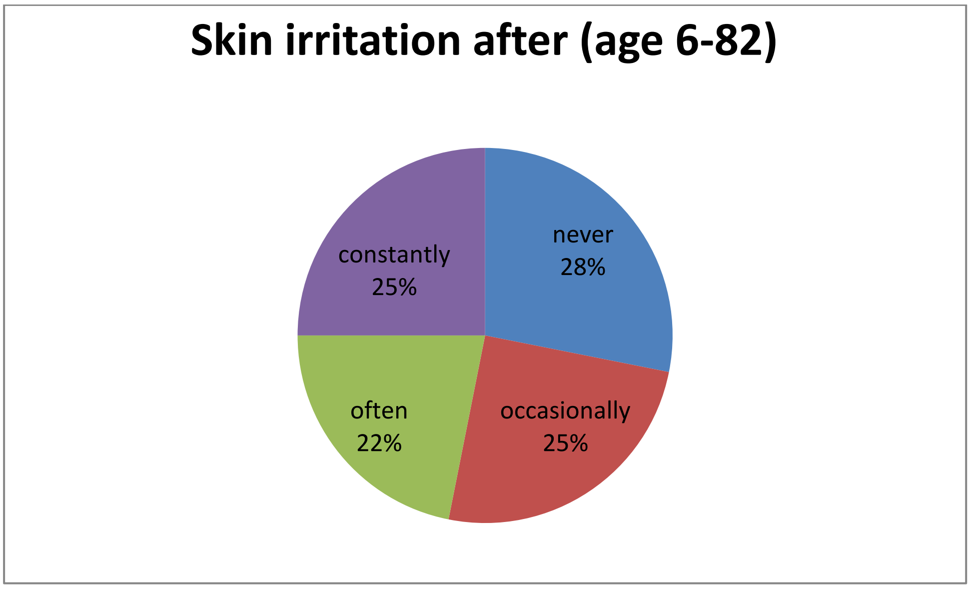

Severe chest pain before (age 6-82)
occasionally 7%
often 1%
constantly 0%
never 92%

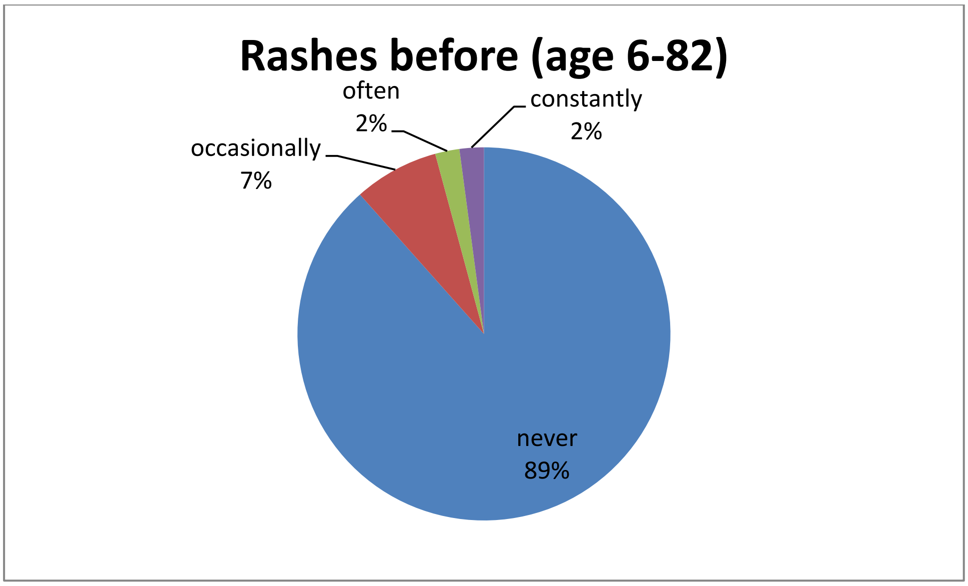

Severe chest pain after (age 6-82)
often 5%
constantly 0%
occasionally 29%
never 66%

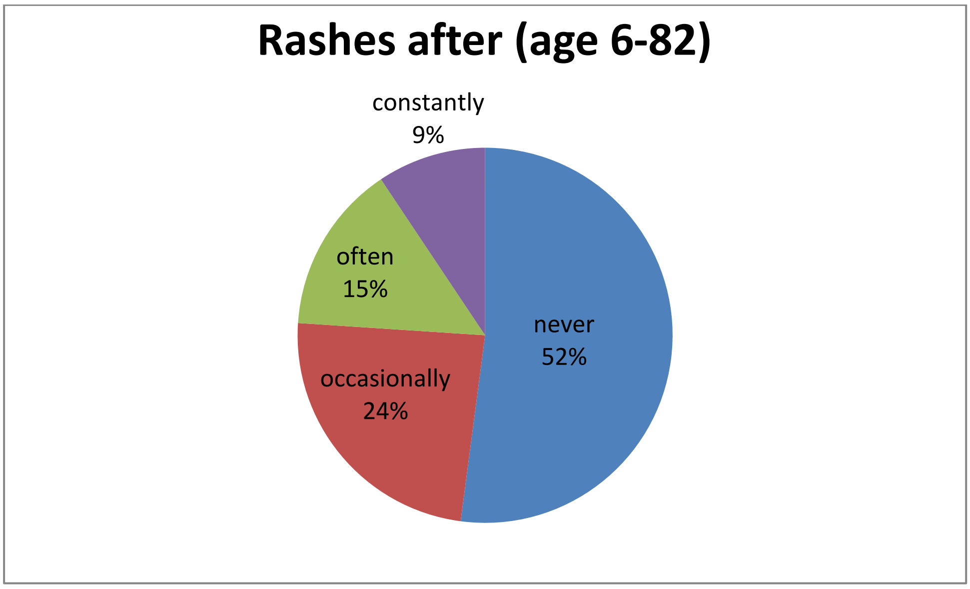

Irregular heart beat before (age 6-82)
occasionally 8%
often 1%
constantly 0%
never 91%

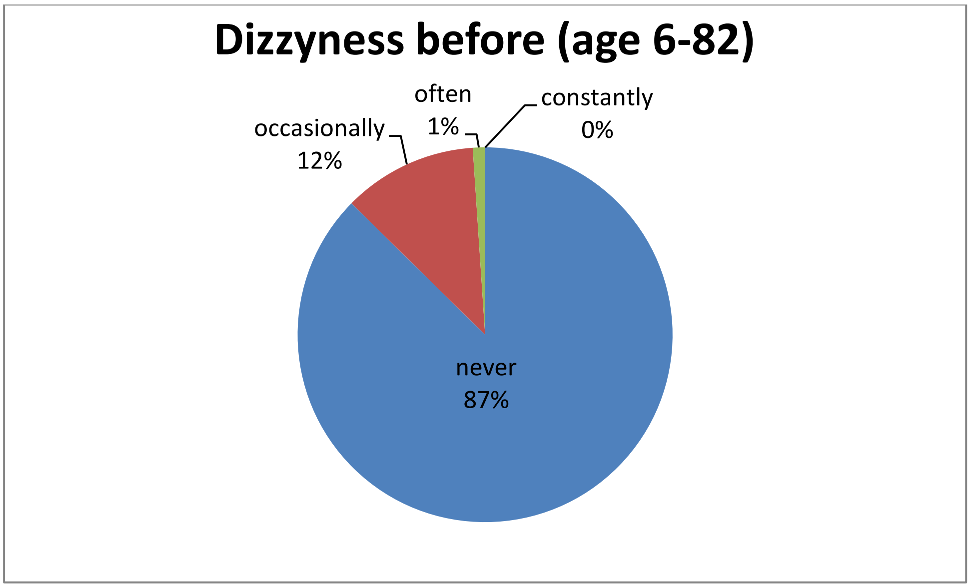

Irregular heart beat after (age 6-82)
constantly 0%
often 7%
occasionally 18%
never 75%

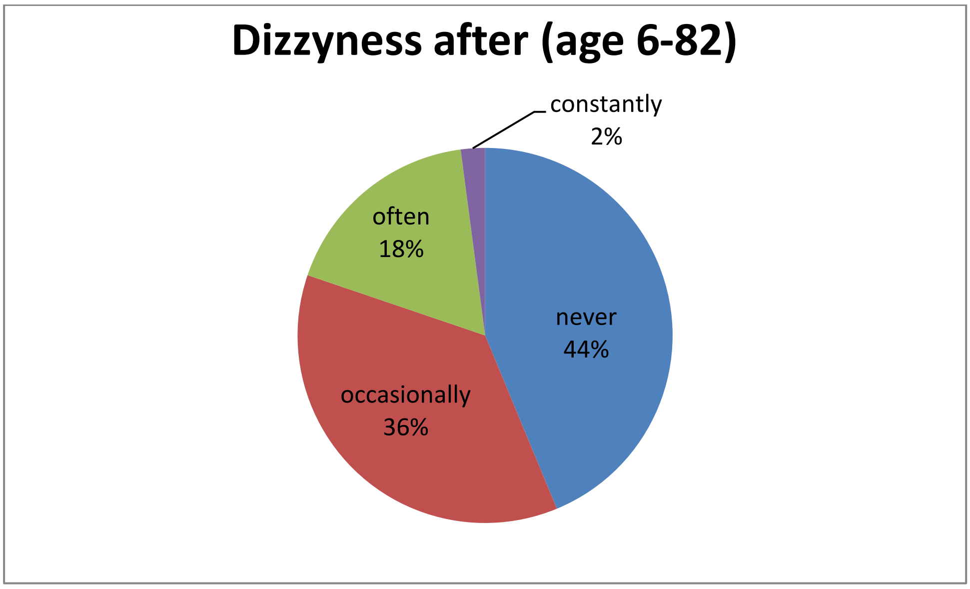

Skin irritation before (age 6-82)
often 1%
constantly 2%
occasionally 14%
never 83%

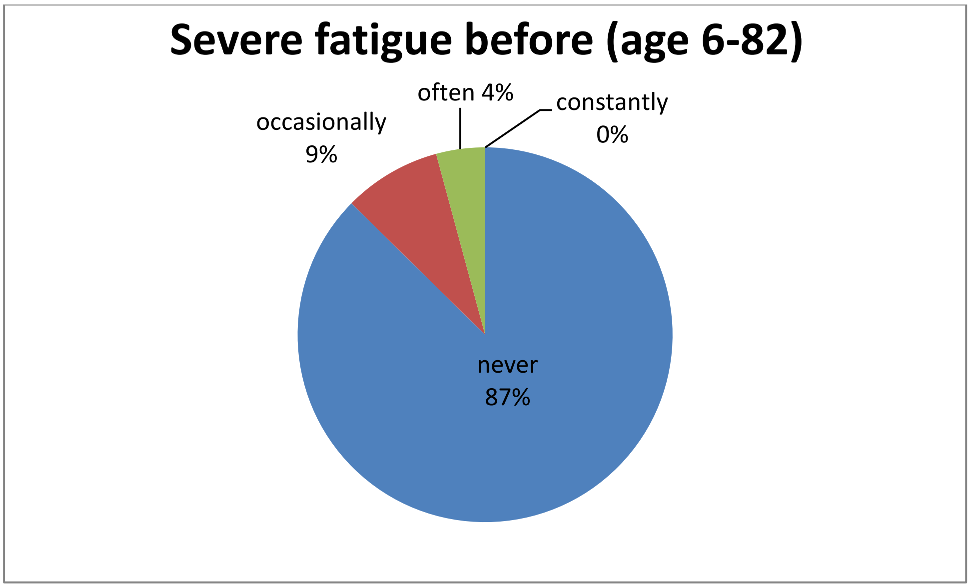

Skin irritation after (age 6-82)
constantly 25%
never 28%
often 22%
occasionally 25%

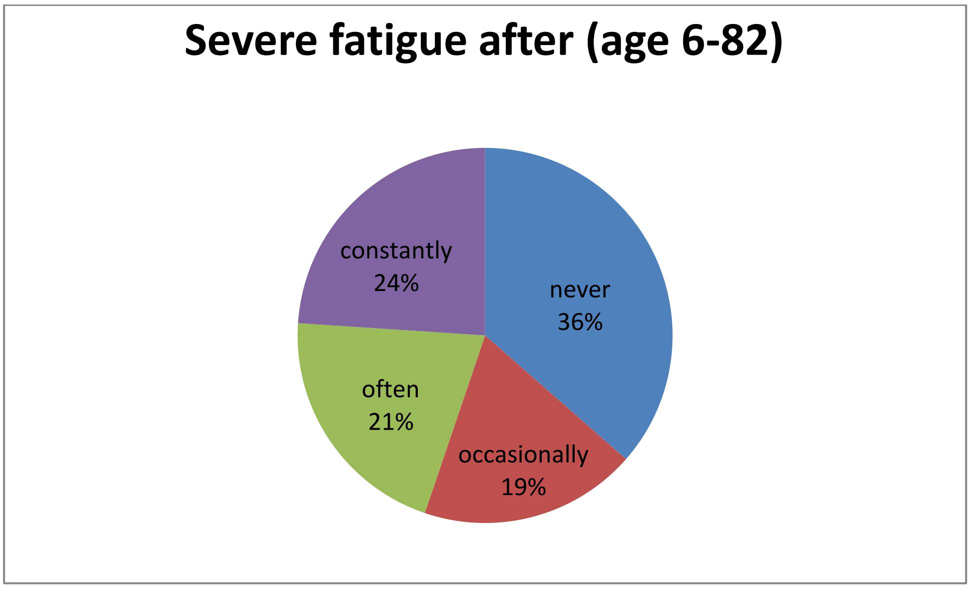

Rashes before (age 6-82)
often
2%
constantly
2%
occasionally
7%
never
89%

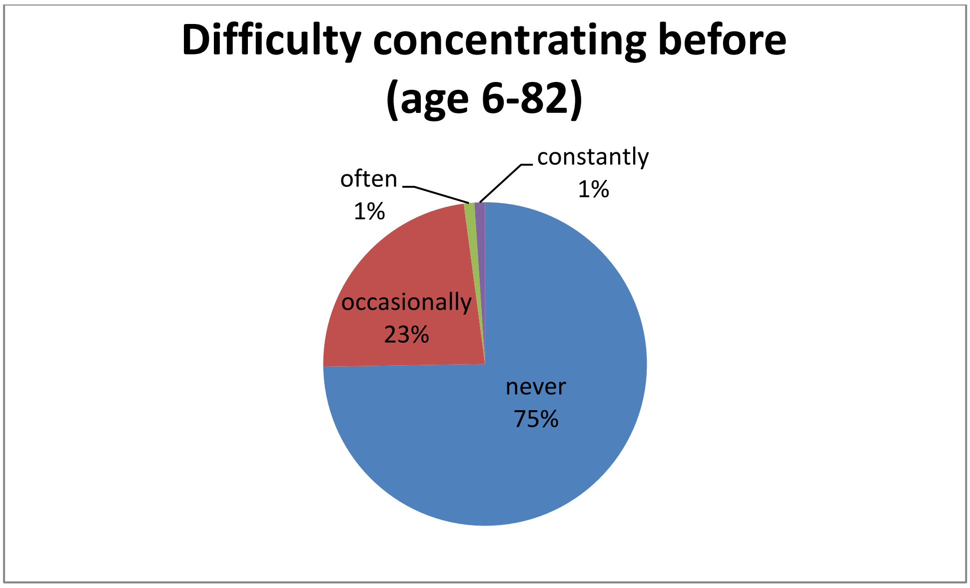

Rashes after (age 6-82)
constantly
9%
often
15%
occasionally
24%
never
52%

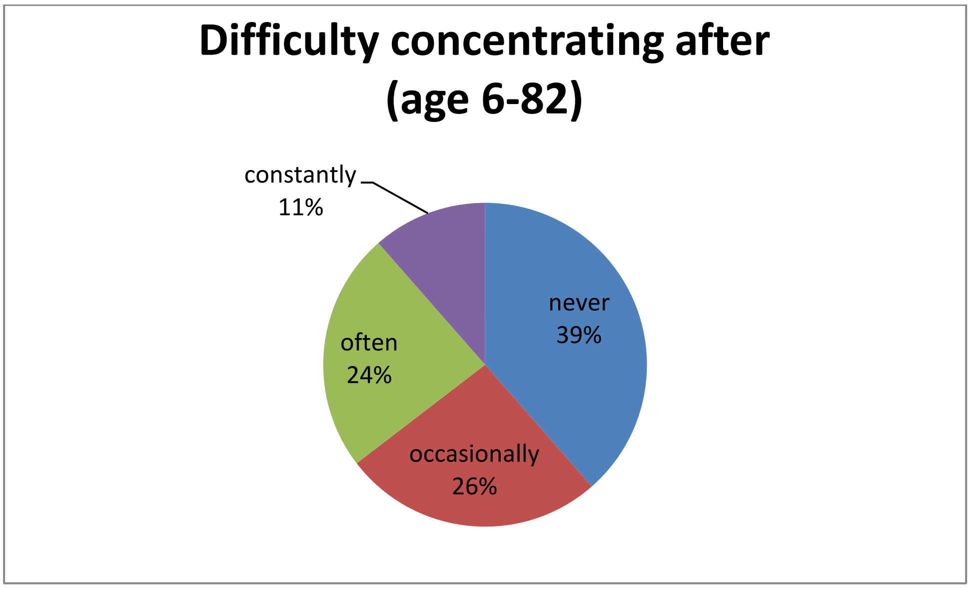

Dizzyness before (age 6-82)
often
1%
constantly
0%
occasionally
12%
never
87%

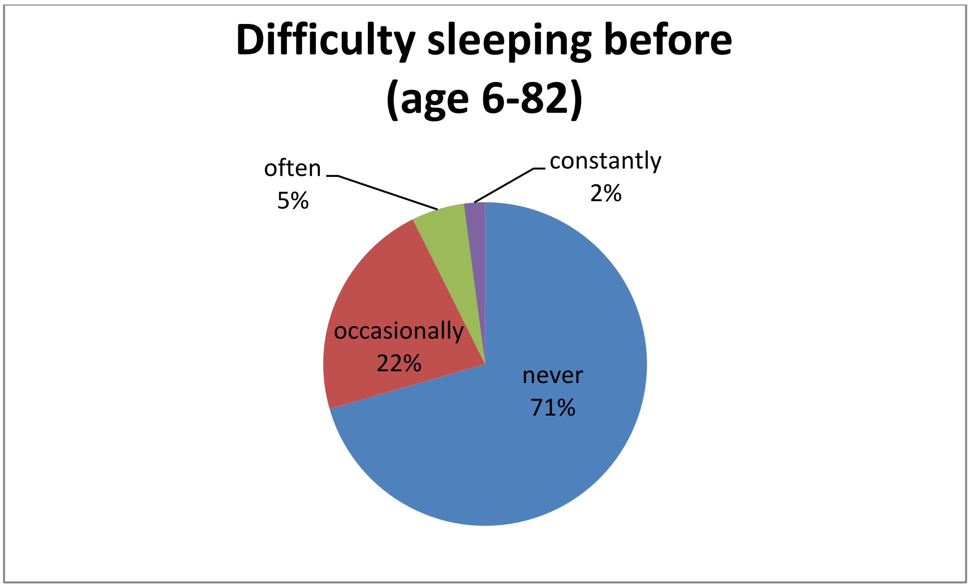

Dizzyness after (age 6-82)
constantly
2%
often
18%
never
44%
occasionally
36%

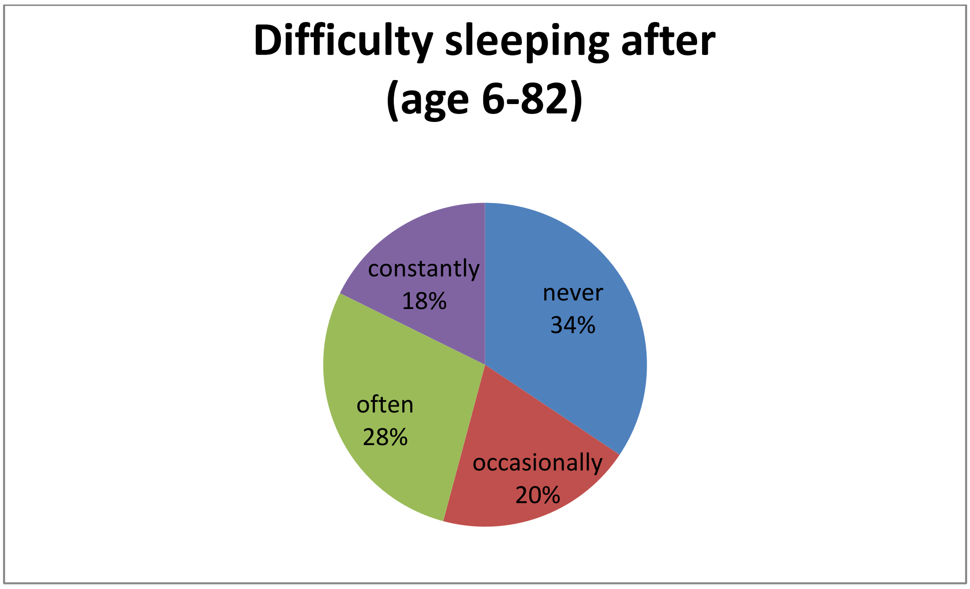

Severe fatigue before (age 6-82)
occasionally
9%
often 4%
constantly
0%
never
87%

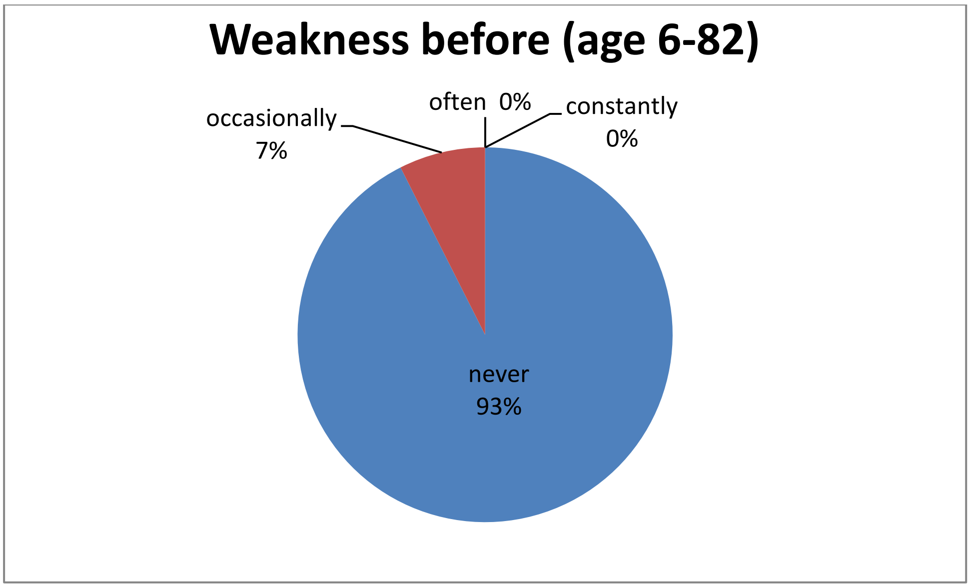

Severe fatigue after (age 6-82)
constantly
24%
never
36%
often
21%
occasionally
19%

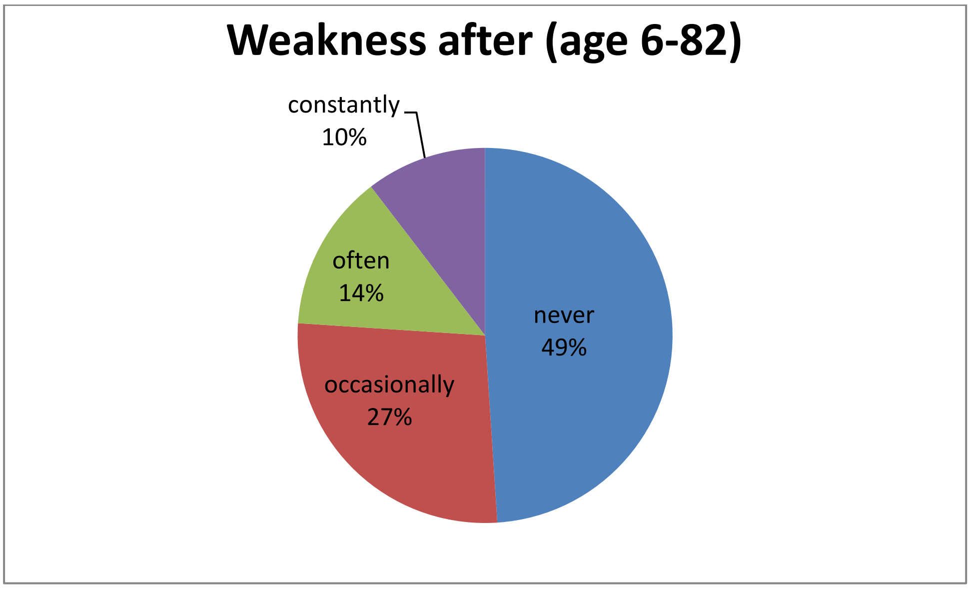

Difficulty concentrating before
(age 6-82)
constantly
1%
often
1%
occasionally
23%
never
75%

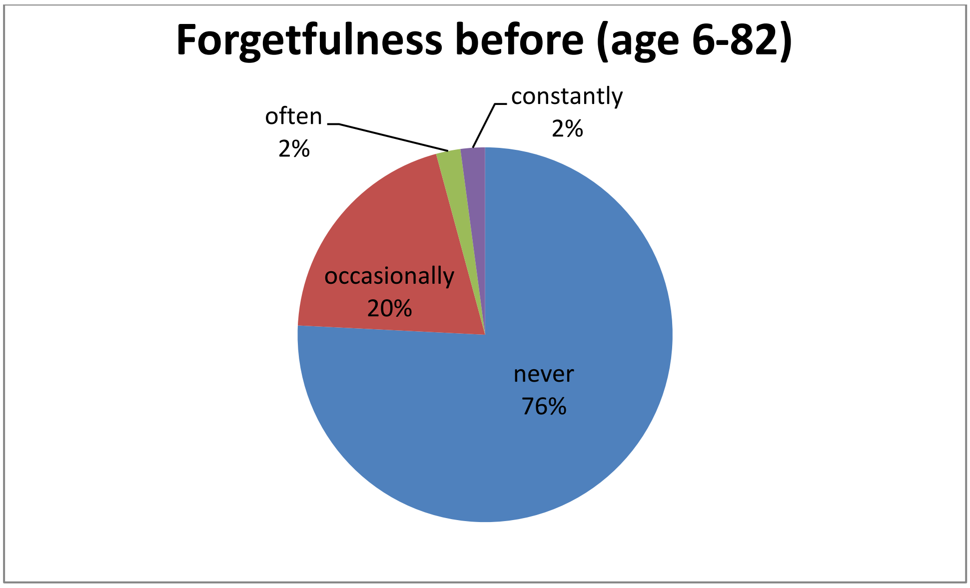

Difficulty concentrating after
(age 6-82)
constantly
11%
often
24%
occasionally
26%
never
39%

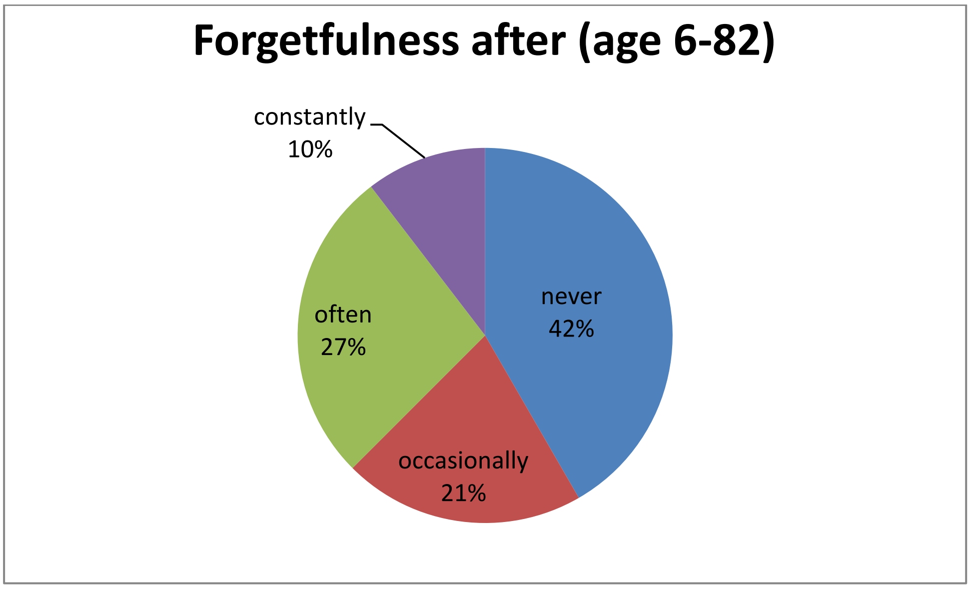

Difficulty sleeping before
(age 6-82)
often
5%
constantly
2%
occasionally
22%
never
71%

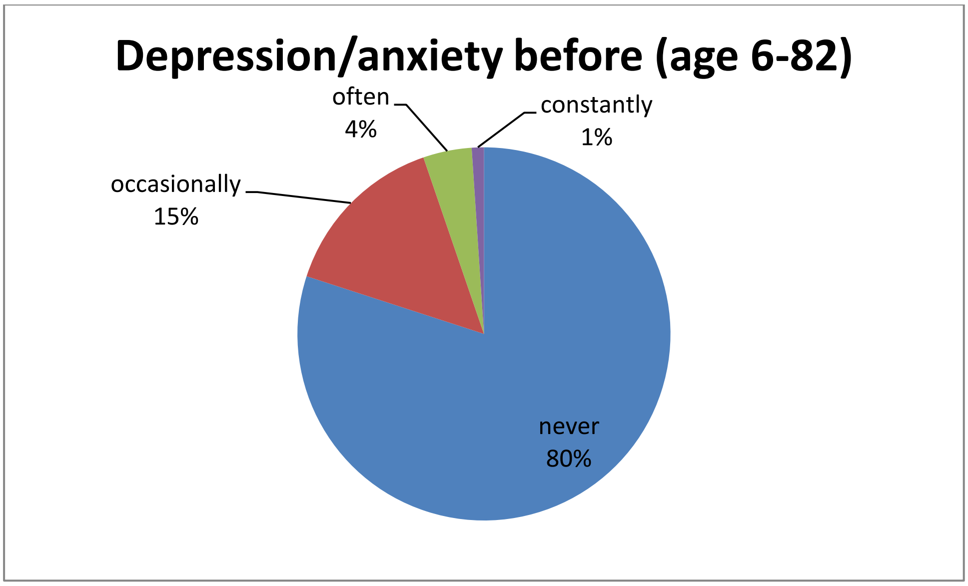

Difficulty sleeping after
(age 6-82)
constantly
18%
never
34%
often
28%
occasionally
20%

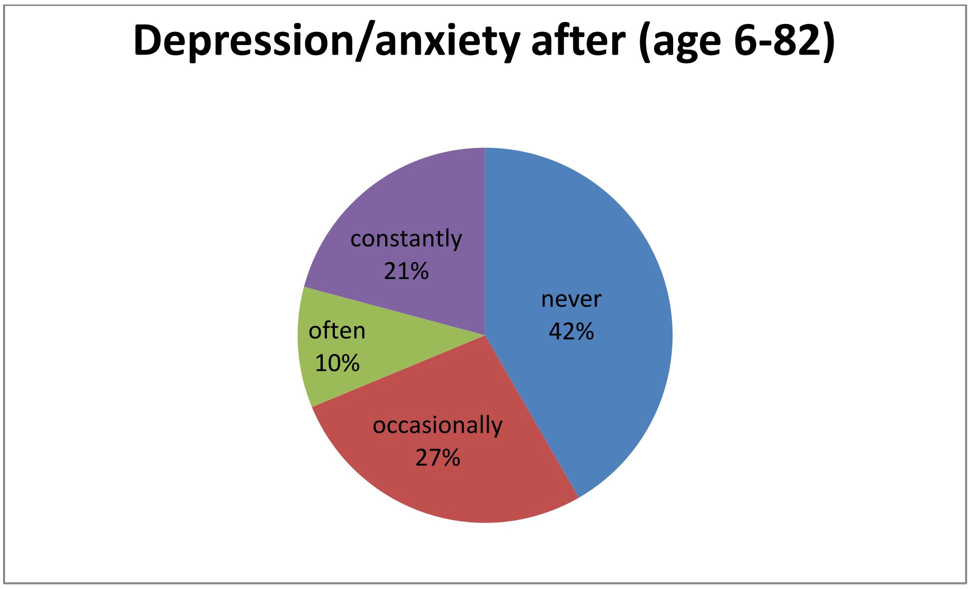

Weakness before (age 6-82)
occasionally
7%
often 0%
constantly
0%
never
93%

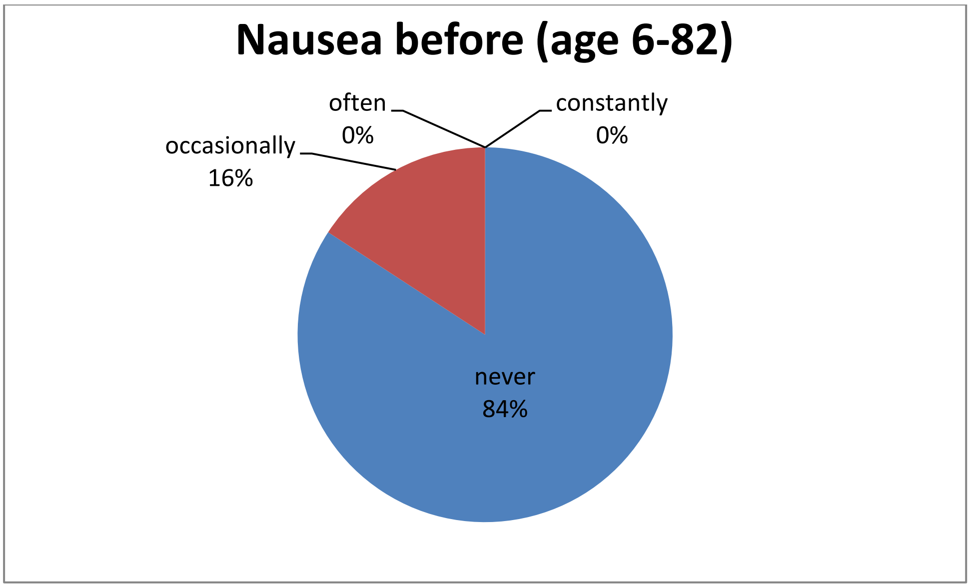

Weakness after (age 6-82)
constantly
10%
often
14%
never
49%
occasionally
27%

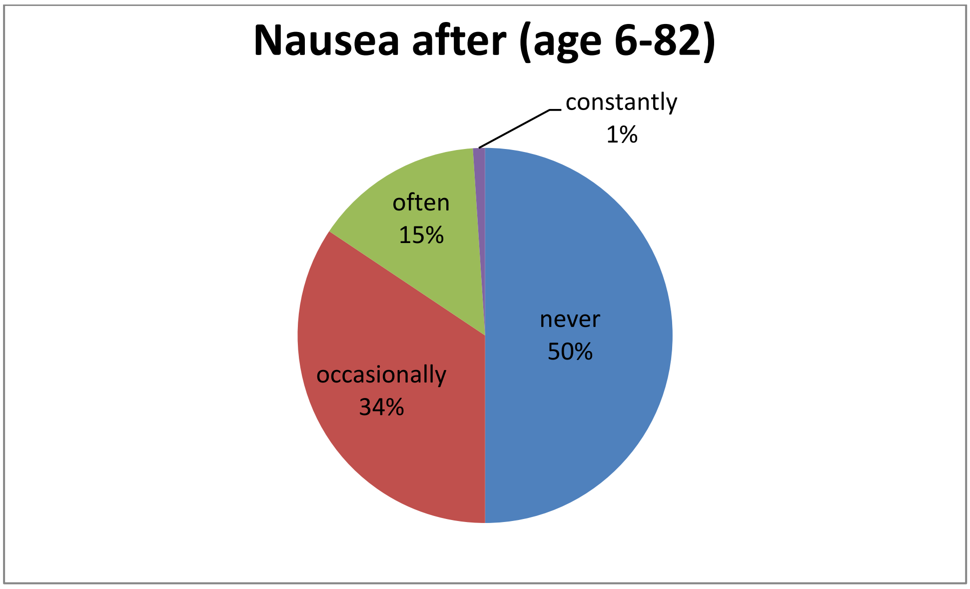

Forgetfulness before (age 6-82)
constantly
2%
often
2%
occasionally
20%
never
76%

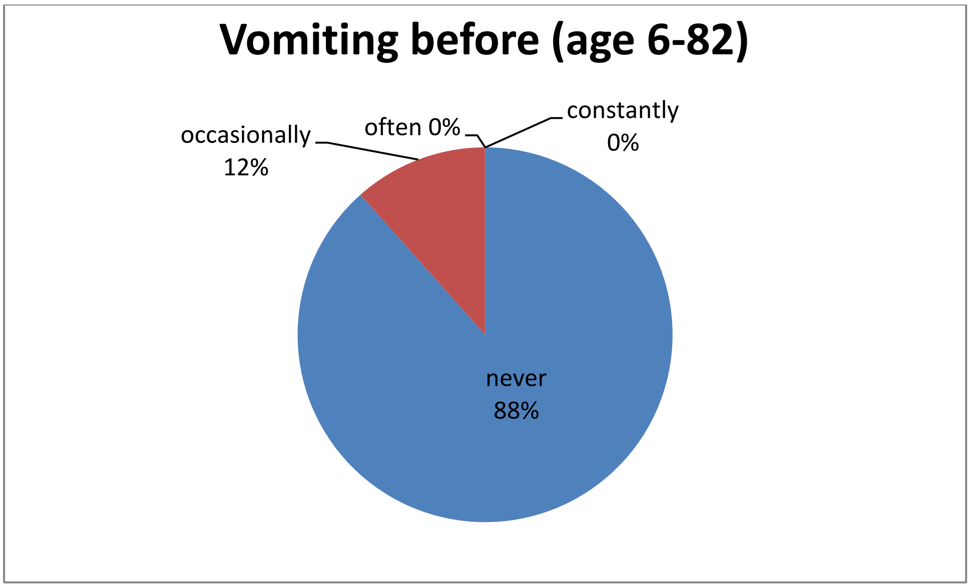

Forgetfulness after (age 6-82)
constantly
10%
often
27%
never
42%
occasionally
21%

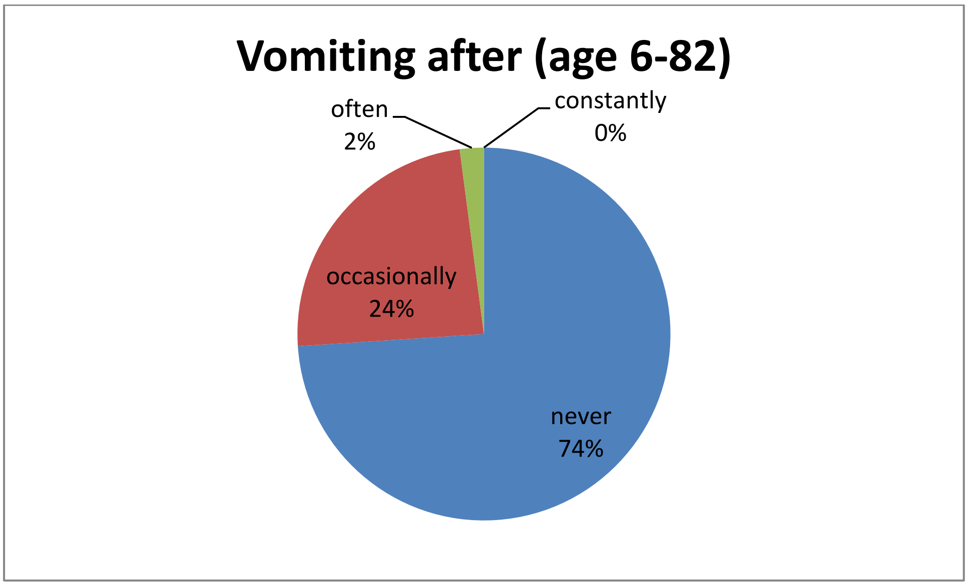

Depression/anxiety before (age 6-82)
often
4%
constantly
1%
occasionally
15%
never
80%

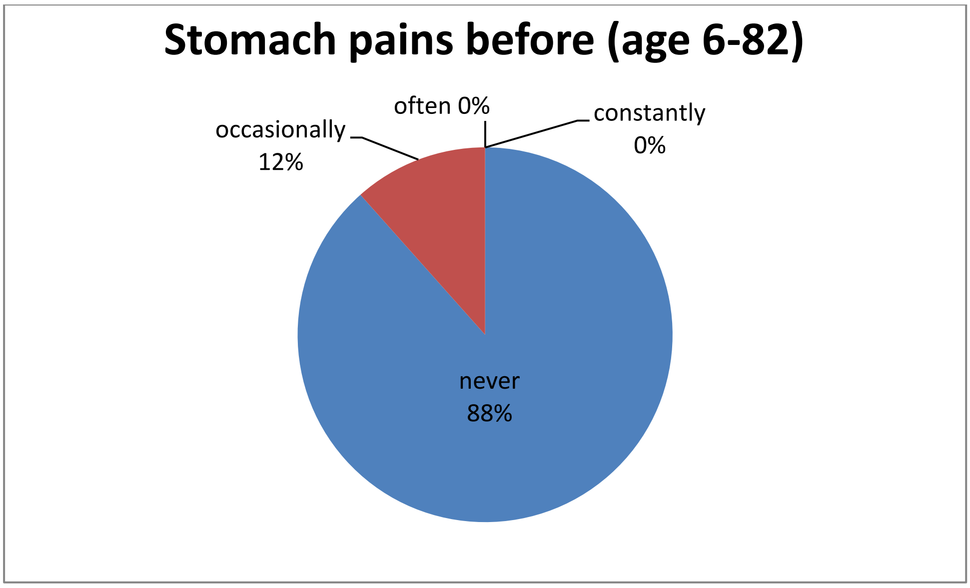

Depression/anxiety after (age 6-82)
constantly
21%
never
42%
often
10%
occasionally
27%

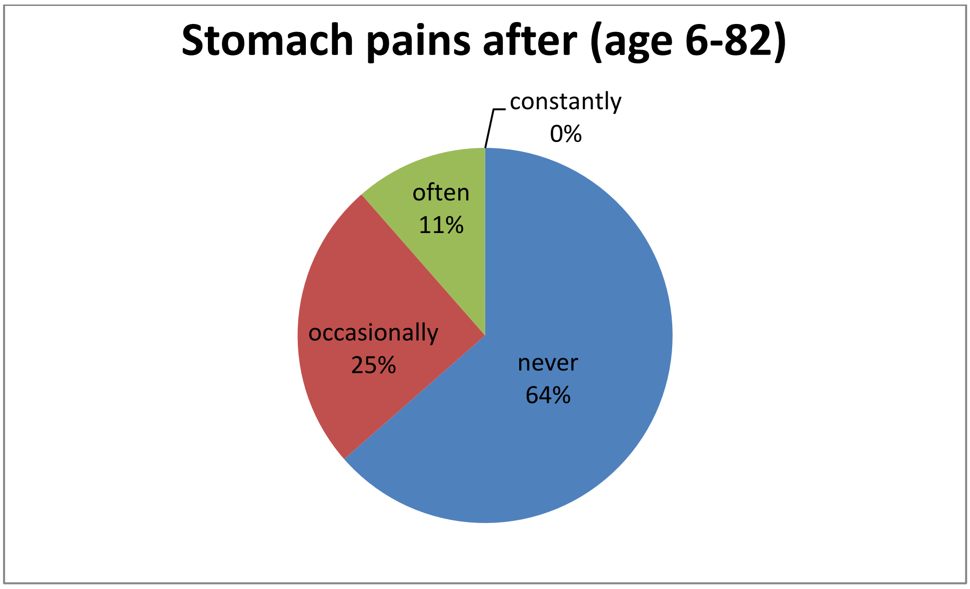

Nausea before (age 6-82)
often
0%
constantly
0%
occasionally
16%
never
84%

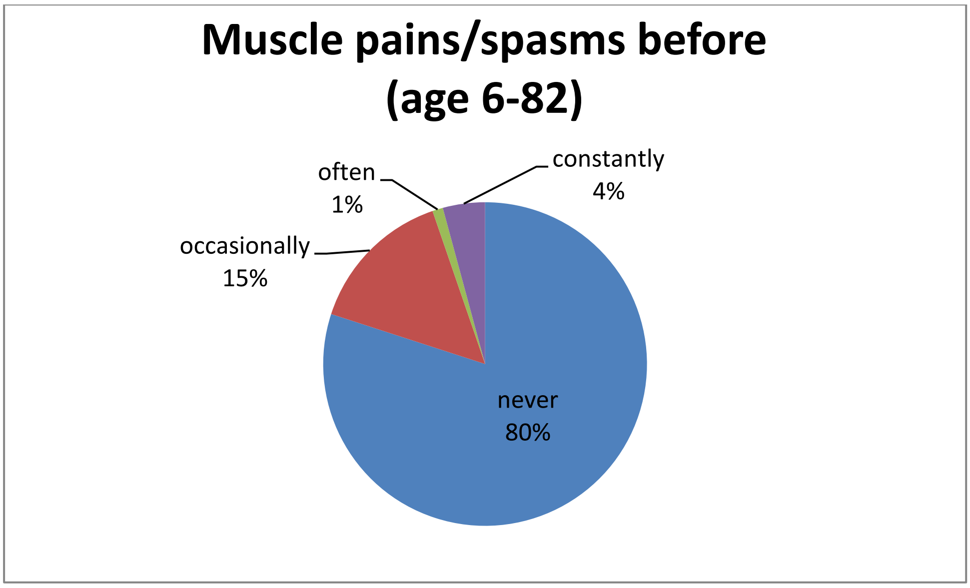

Nausea after (age 6-82)
constantly
1%
often
15%
never
50%
occasionally
34%

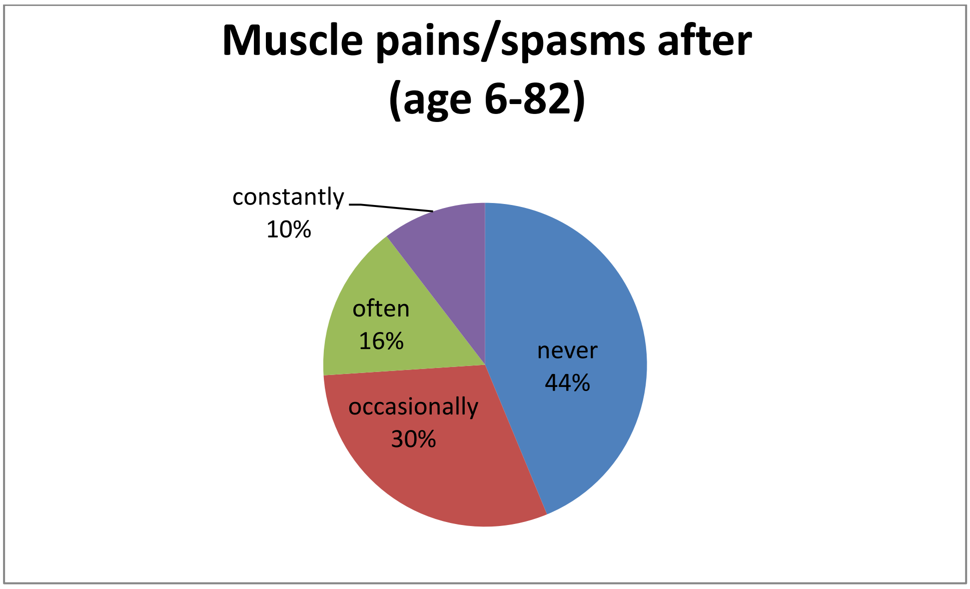

Vomiting before (age 6-82)
occasionally 12%
often 0%
constantly 0%
never 88%

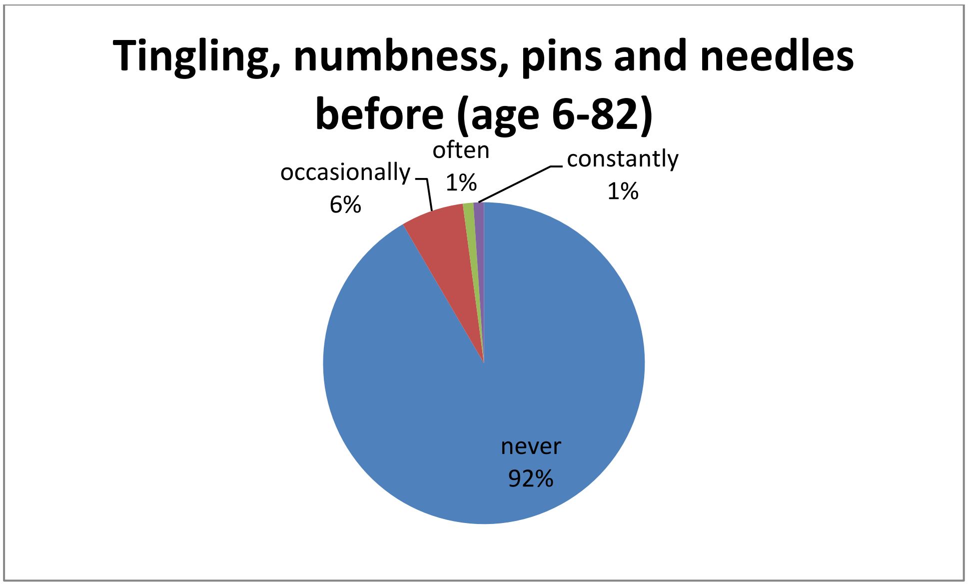

Vomiting after (age 6-82)
often 2%
constantly 0%
occasionally 24%
never 74%

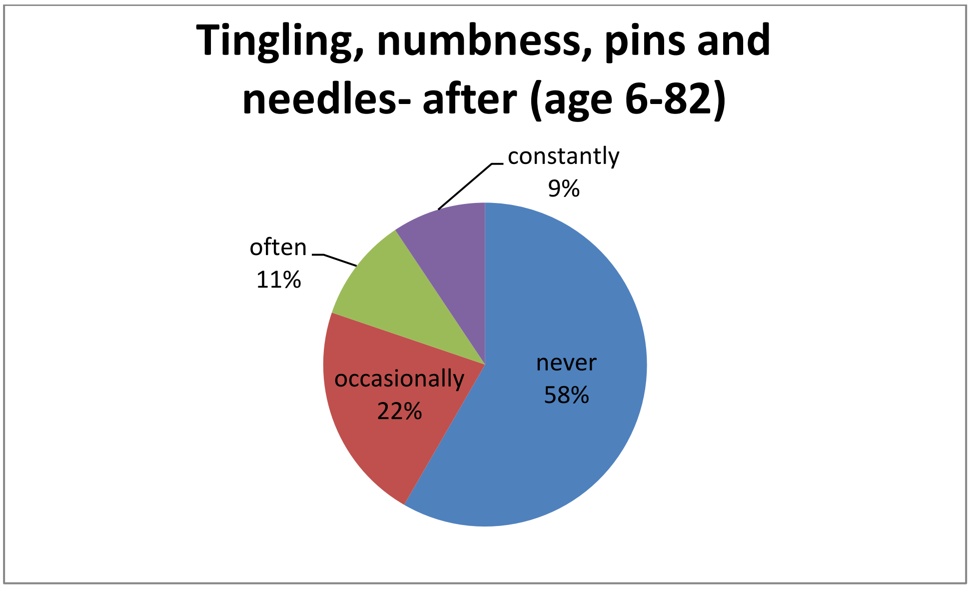

Stomach pains before (age 6-82)
often 0%
occasionally 12%
constantly 0%
never 88%

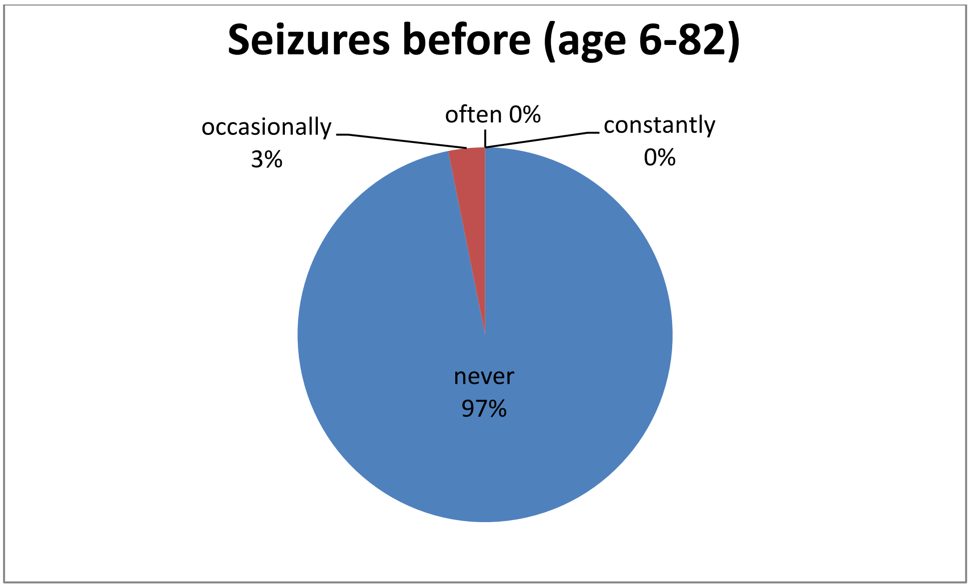

Stomach pains after (age 6-82)
constantly 0%
often 11%
occasionally 25%
never 64%

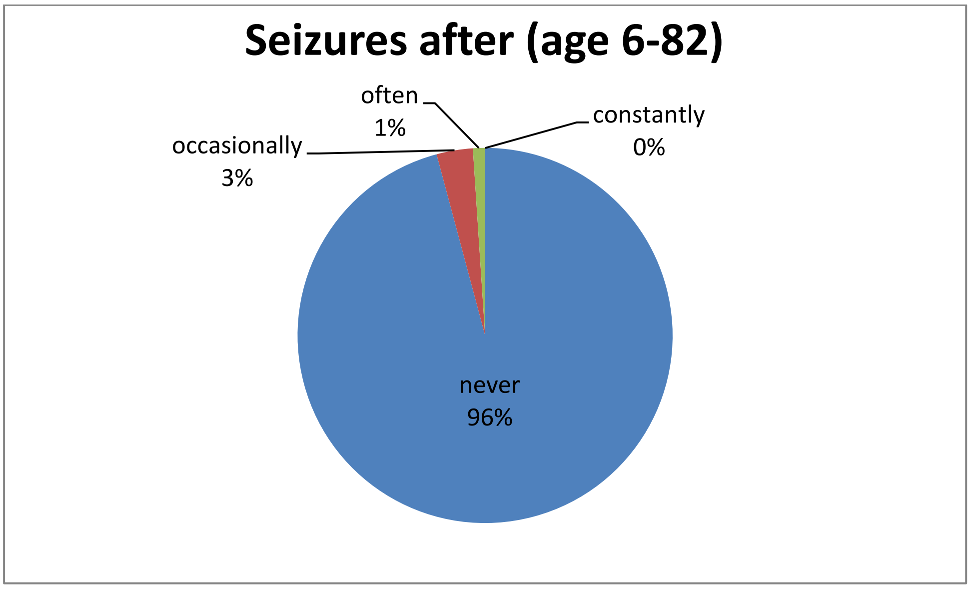

Muscle pains/spasms before
(age 6-82)
often
1%
constantly
4%
occasionally
15%
never
80%

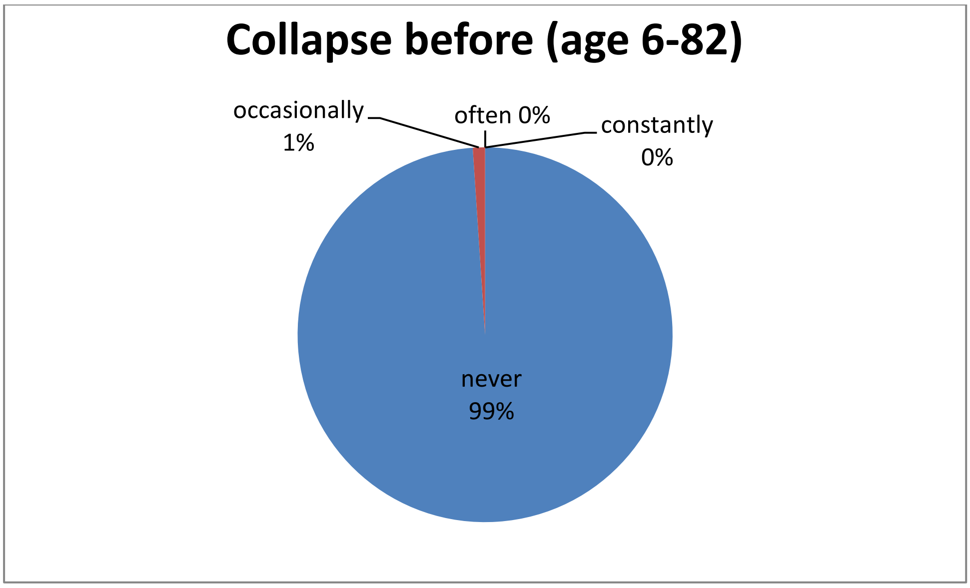

Muscle pains/spasms after
(age 6-82)
constantly
10%
often
16%
never
44%
occasionally
30%

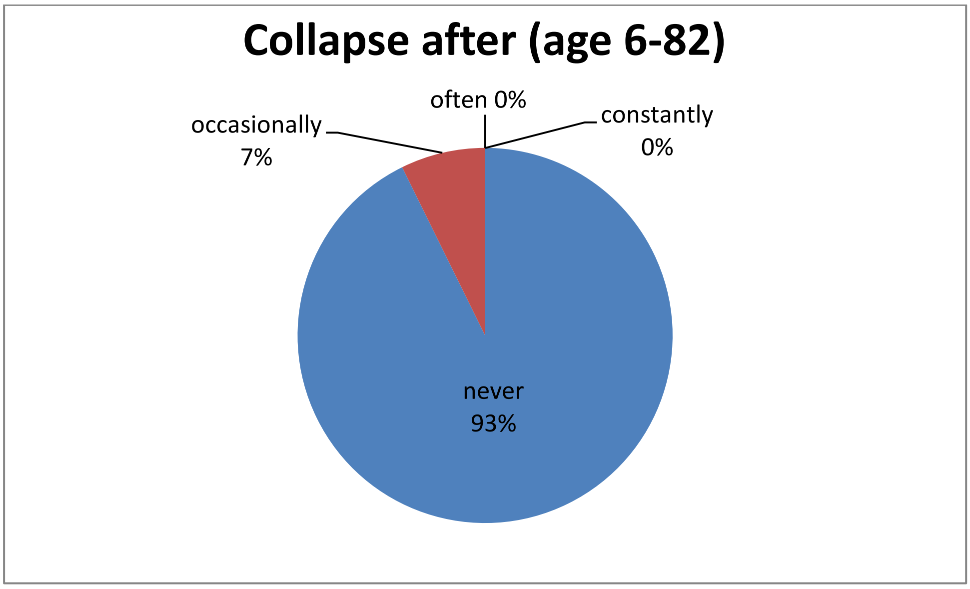

Tingling, numbness, pins and needles before (age 6-82)
occasionally 6%
often 1%
constantly 1%
never 92%

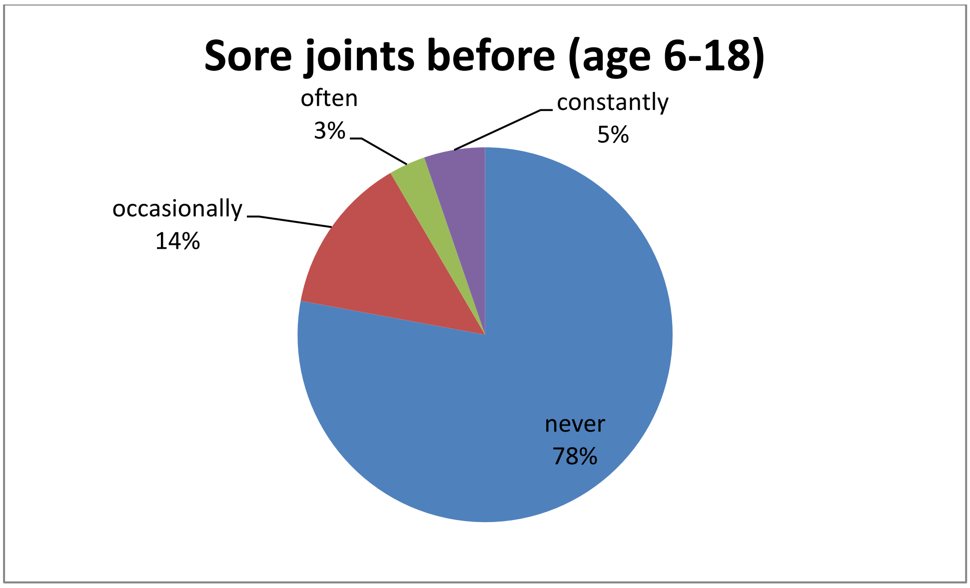

Tingling, numbness, pins and needles- after (age 6-82)
constantly 9%
often 11%
occasionally 22%
never 58%

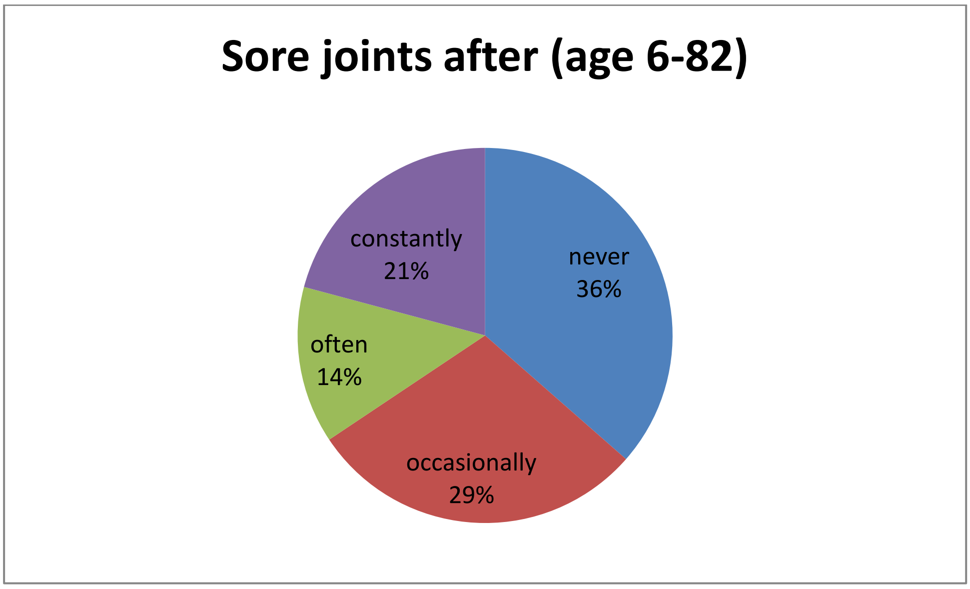

Seizures before (age 6-82)
occasionally 3%
often 0%
constantly 0%
never 97%


Seizures after (age 6-82)
often 1%
occasionally 3%
constantly 0%
never 96%

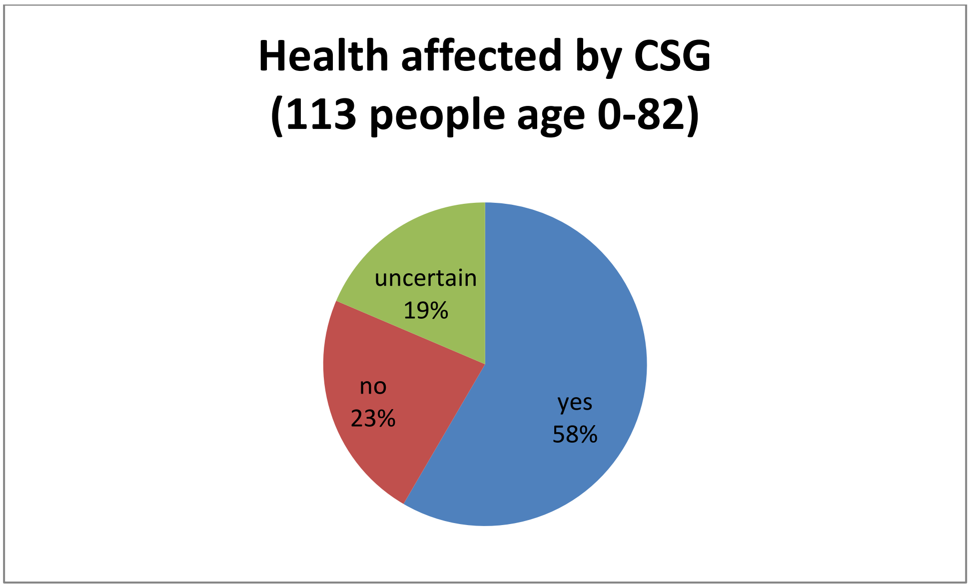

Collapse before (age 6-82)
occasionally 1%
often 0%
constantly 0%
never 99%


Collapse after (age 6-82)
occasionally 7%
often 0%
constantly 0%
never 93%

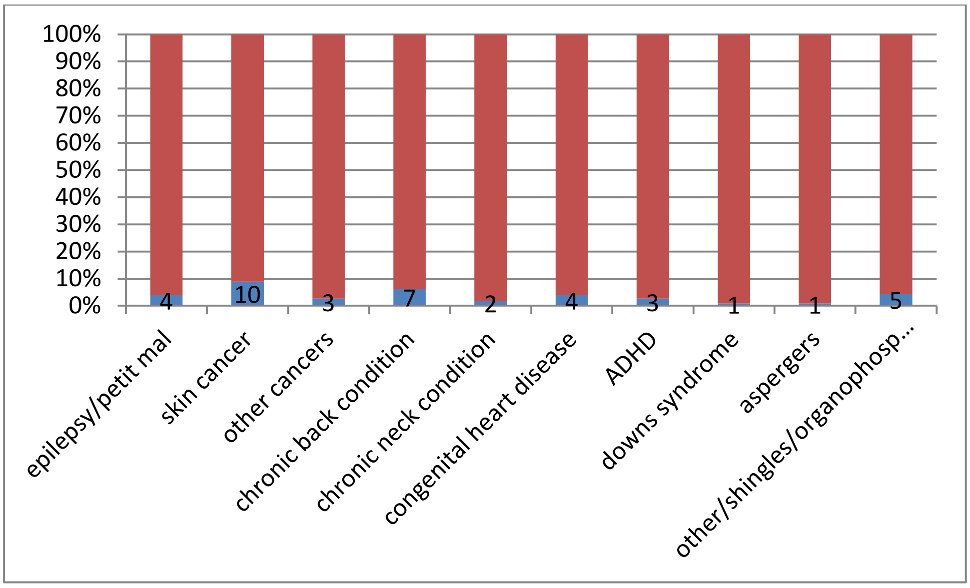

Sore joints before (age 6-18)
often
3%
constantly
5%
occasionally
14%
never
78%

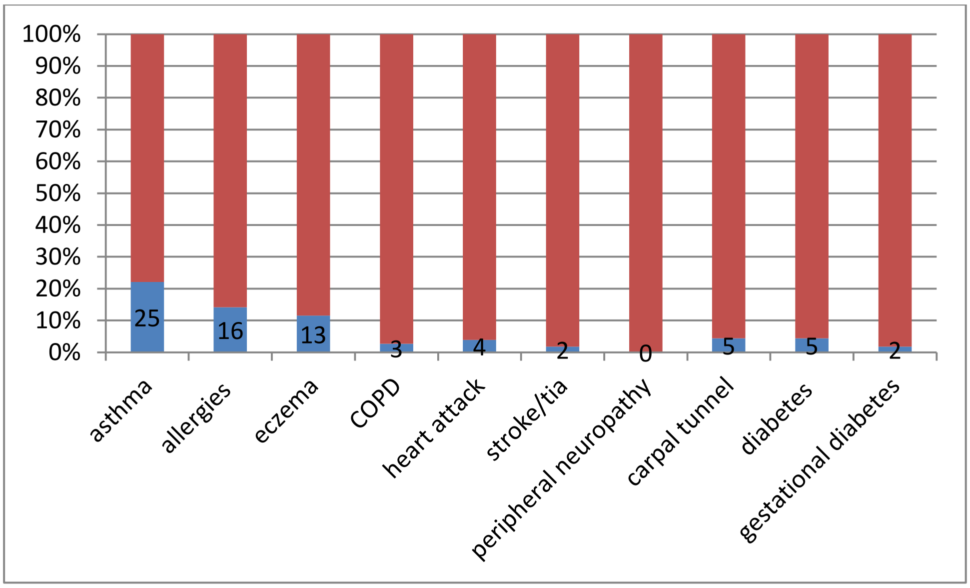

Sore joints after (age 6-82)
constantly
21%
never
36%
often
14%
occasionally
29%

Percentage Total Affected age 0-82 - Pie Chart



Diagnoses prior to CSG age 0-82





Diagnoses after CSG

Unexplained marker for ovarian cancer

Asthma

Attention seeking

Chronic cough (undiagnosed)

Depression/anxiety

Asthma

Hypertension

Petit mal

Anxiety/reflux /asthma/ chest infection

Scabies (unresponsive to treatment)

COPD/ thyroid lump/helicobacter/ diverticulosis/ dermatitis
Low/normal calcium
Constant "flu"
Eczema
Cerebral haemorrhage/secondary hydrocephalus
Anxiety/depression
Pneumonia 6 times since Oct 2012/ abnormal PSA
Skin cancers/ heart issues
Pulmonary emboli post cholecystectomy/ sleep apnoea
Suicidal
Prolapsed disc
Depression/anxiety
Allergies(told environmental)
Pleurisy ?viral
Hashimotos/gastritis/diverticulosis /hypertension
COPD/ Barrett's oesophagus
Arthritis
Ectropian
Skin cancer
Recurrent chest infections/hypertension
Carpal tunnel
Peripheral neuropathy/ renal impairment
Ross River
Depression/anxiety

APPENDIX C – PERCEIVED IMPACTS ON ANIMALS/ BIRDS

Feathers falling off birds and chickens. Skin irritation in dogs, bald patches.

No frogs for 3 years until 2012/2013 season.

Frogs back after the rains.

Horse keeps getting sores on its legs. Less birds- redwings. Used to be heaps. Not here for years.

At one points budgies and chickens died. Turkeys died. No sign of disease. Well one day – dead the next. Parent budgies and babies all dead inside breeding box in the morning. Birds dead outside. 3 chickens died at point of lay. 20 week old turkeys died.

Didn't notice less birds. Goannas disappeared in the last few months-kept finding dead goannas. Cane toads were brought in with the pipes. Puts fresh water and food out for the birds.

Haven't noticed anything

Dog died 10 months after arriving in Tara-heart attack, gums white. Died overnight. Healthy cat- age 8 years, suddenly sick. Persian cat, developed kidney problems, died.

Haven't noticed any problems

More cane toads. Less small birds- no redcaps, robins, wrens. Plants aren't flowering as used to.

Haven't noticed anything

Haven't noticed anything

Increased road kill- emus, echidnas, goannas, snakes, blue tongue lizards, kangaroos, wallabies

No unusual illness

Within a 6 month period dog lost fur, couldn't walk properly, stopped eating and two placid family dogs (raised from pups) -overnight became vicious, had to be put down.

Native animals disappeared especially frogs. Some back in last few weeks in the rains.

Haven't noticed anything

Dogs vomiting after being near surface water

No unusual illness. puts out fresh water for wildlife

Used to be a lot of wallabies, none recently- very scarce. Birds ok mainly king parrot, rosella, redwing, galah, less snakes, frogs ok

Haven't noticed anything

Rarely see native animals. Previously lots of emus, kangaroos, parrots, galahs

More roos- moved away from traffic nearer wells.

Lots of frogs

Dog bites skin until he has no fur. Other dog that doesn't go outside is ok. Used to be a lot of parrots, red parrots, king parrots, now don't see them

Dogs- rashes after swimming in the dam. No birds, kangaroos or wallabies will drink from the dam now- they used to. Puts out rainwater for the wild animals.

Unexpected death of two kangaroos hand raised from birth. Gives kangaroos and wildlife tank water.

Ample wildlife

Used to be lots of birds and kangaroos- not now. Less green and red/black frogs.

Haven't noticed anything

Nothing unexpected

Dogs rashes, birds loss of feathers.

Hasn't seen a snake in the past seven years. No goannas- previously plentiful. Uses to be lots of birds, now infrequently. Has lots of native trees, no birds even when they are in flower.

Hasn't noticed anything

Cane toads came in with the pipeline, large influx of large adult cane toads. (? Came in with machinery and pipes) rarely see snakes now. Less kangaroos- ?because of road kill

Puppies lost their fur. Loss of frogs for 18 months during drilling. Coming back – finding dead frogs now.

[1] Public servants tasked with approving massive CSG projects were blindsided by demands to approve two in two weeks http://www.couriermail.com.au/news/public-servants-tasked-with-approving-to-massive-csg-projects-were-blindsided-by-demands-to-approve-two-in-two-weeks/story-e6freon6-1226574952587
[2] Coal seam gas in the Tara region: summary risk assessment of health complaints and environmental monitoring data report www.health.qld.gov.au/publications/csg/documents/report.pdf
[3] Curriculum Vitae Dr Keith Adam http://education.qld.gov.au/asbestos/pdfs/keith-adam-cv.pdf
[4] Letter, Rick Wilkinson, Sydney Morning Herald http://www.smh.com.au/national/letters/churches-fail-to-put-reasoned-argument-20130118-2cz9s.html
[5] Gasfields Community Support Group http://westerndowns.group-action.com/2012/04/27/gasfield-community-support-group-3/
[6] Bernard M GoldStein MD 'The Precautionary Principle Also Applies to Public Health Actions' http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1446778/
[7] ABC News No link found between CSG and health complaints http://www.abc.net.au/news/2013-03-21/no-link-found-between-csg-and-health-complaints/4586344
[8] Toluene http://www.epa.gov/ttnatw01/hlthef/toluene.html
[9] Queensland Government, Dept of Environment and Heritage Protection, BTEX Chemicals http://www.ehp.qld.gov.au/management/non-mining/btex-chemicals.html
[10] QGC – Tara leaking GSQ wells investigation report 1 June 2010 http://mines.industry.qld.gov.au/assets/petroleum-pdf/tara_leaking_well_investigation_report.pdf
[11] Submission on National Greenhouse and Energy Reporting (Measurement) Determination 2012 - Fugitive Emissions from Coal Seam Gas http://www.scu.edu.au/coastal-biogeochemistry/download.php?doc_id=12515&site_id=258&file_ext=.pdf
[12] Condamine River Gas Seep Investigation Report http://www.industry.qld.gov.au/lng/condamine-river-gas-seep.html
[13] Gas Today, Challenges in CSG gathering system design http://gastoday.com.au/news/challenges_in_csg_gathering_system_design/064554/
[14] About coal seam gas http://www.ehp.qld.gov.au/management/coal-seam-gas/index.html
[15] Queensland Government, Department of Environment and Heritage Protection http://www.ehp.qld.gov.au/management/non-mining/btex-chemicals.html
[16] Sydney Morning Herald - Carcinogens found in CSG project http://news.smh.com.au/breaking-news-national/carcinogens-found-in-csg-project-20110828-1jg77.html
[17] Researchers Find Surprises When Analyzing DNA From Fracking Site http://www.redorbit.com/news/science/1112743155/fracking-well-microbes-bacteria-water-120612/
[18] WHO Air Quality Guidelines for Europe http://www.euro.who.int/__data/assets/pdf_file/0017/123056/AQG2ndEd_5_2benzene.pdf
[19] p-Nonyl-Phenol: An Estrogenic Xenobiotic Released from "Modified" Polystyrene http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1519400/pdf/envhper00388-0165.pdf
[20] Diamanti-Kandarakis et al. Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement *Endocrine Reviews* June 1, 2009 vol. 30 no. 4 293-342 http://edrv.endojournals.org/content/30/4/293.full
[21] Chemical and Biological Risk Assessment for Natural Gas Extraction in New York. Ronald E. Bishop, Ph.D., CHO, Chemistry & Biochemistry Department, State University of New York, College at Oneonta, Sustainable Otsego March 28, 2011 www.sustainableotsego.org/Risk%20Assessment%20Natural%20Gas%20Extraction-1.htm
[22] Toxicological profile for Acrolein http://www.atsdr.cdc.gov/toxprofiles/tp124.pdf
[23] Human health risk assessment of air emissions from development of unconventional natural gas resources May 2012 http://www.ncbi.nlm.nih.gov/pubmed/22444058
[24] Natural Gas Operations from a Public Health Perspective Sept 2011 http://www.endocrinedisruption.com/chemicals.journalarticle.php
[25] Lloyd-Smith, M. & Senjen, R., Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate, National Toxics Network, September 2011 http://ntn.org.au/wp/wp-content/uploads/2012/04/NTN-CSG-Report-Sep-2011.pdf

[26] Gas Patch Roulette
http://www.earthworksaction.org/library/detail/gas_patch_roulette_full_report#.UWBLDntwbIU
[27] Environmental pathways of potential impacts to human health from oil and gas development in northeast British Columbia, Canada http://www.nrcresearchpress.com/doi/abs/10.1139/a2012-005#.UWBMJ3twbIU
[28] An Exploratory Study of Air Quality near Natural Gas Operations
http://cogcc.state.co.us/RR_HF2012/setbacks/CommentDocs/Public/TEDX_Setbacks_Comments.pdf
[29] Update on Hydrofracking http://aapdistrictii.org/update-on-hydrofracking/
[30] Worker Exposure to Crystalline Silica During Hydraulic Fracturing http://blogs.cdc.gov/niosh-science-blog/2012/05/silica-fracking/
[31] Update on Hydrofracking http://aapdistrictii.org/update-on-hydrofracking/

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IMPACTS OF GAS DRILLING ON HUMAN AND ANIMAL HEALTH

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ABSTRACT

Environmental concerns surrounding drilling for gas are intense due to expansion of shale gas drilling operations. Controversy surrounding the impact of drilling on air and water quality has pitted industry and lease-holders against individuals and groups concerned with environmental protection and public health. Because animals often are exposed continually to air, soil, and groundwater and have more frequent reproductive cycles, animals can be used as sentinels to monitor impacts to human health. This study involved interviews with animal owners who live near gas drilling operations. The findings illustrate which aspects of the drilling process may lead to health problems and suggest modifications that would lessen but not eliminate impacts. Complete evidence regarding health impacts of gas drilling cannot be obtained due to incomplete testing and disclosure of chemicals, and nondisclosure agreements. Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment on an enormous scale.

Keywords: hydraulic fracturing, shale gas drilling, veterinary medicine, environmental toxicology

> At what point does preliminary evidence of harm become definitive evidence of harm? When someone says, "We were not aware of the dangers of these chemicals back then," whom do they mean by *we*?
>
> —Sandra Steingraber, *Living Downstream* (Da Capo Press, 2010)

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Communities living near hydrocarbon gas drilling operations have become de facto laboratories for the study of environmental toxicology. The close proximity of these operations to small communities has created a variety of potential hazards to humans, companion animals, livestock and wildlife. These hazards have become amplified over the last 20 years, due in part to the large-scale development of shale gas drilling (horizontal drilling with high-volume hydraulic fracturing), encouraged by the support of increased drilling and exploration by U.S. government agencies [1]. Yet this large-scale industrialization of populated areas is moving forward without benefit of carefully controlled studies of its impact on public health. As part of an effort to obtain public health data, we believe that particular attention must be paid to companion animals, livestock, and wildlife, as they may serve as sentinels for human exposures, with shorter lifetimes and more opportunity for data collection from necropsies.

All phases of hydrocarbon gas production involve complex mixtures of chemical substances. For example, in hydraulic fracturing fluids, chemical substances other than water make up approximately 0.5 to 1 percent of the total volume; however, the very large volumes used require correspondingly large volumes of a variety of compounds. These substances range from the relatively benign to the highly toxic. Some of these are reported to the public and others are not, but the quantities and proportions used are largely considered trade secrets. In addition to these added chemicals, naturally occurring toxicants such as heavy metals, volatile organics, and radioactive compounds are mobilized during gas extraction and return to the surface with the gas/chemical mix (wastewater); of the 5.5 million gallons of water, on average, used to hydraulically fracture a shale gas well one time [2], less than 30 percent to more than 70 percent may remain underground [3]. Hydraulic fracturing takes place over 2 to 5 days and may be repeated multiple times on the same well over the course of the potential 25- to 40-year lifetime of a well [4]. Many of these chemicals are toxic and have known adverse health effects, which may be apparent only in the long term. A discussion of these compounds and their health effects is beyond the scope of this article; however, Colborn et al. [5] have analyzed this topic in depth.

The large-scale use of chemicals with significant toxicity has given rise to a great deal of public concern, and an important aspect of the debate concerns the level of proof required to associate an environmental change with activities associated with gas drilling. Environmental groups typically invoke the precautionary principle [6]. That is, if an action is suspected of causing harm to the environment, then in the absence of a scientific consensus, the burden of proof falls on the individual or organization taking the action. The oil and gas industry has typically rejected this analysis and has approached the issue in a manner similar to the tobacco industry that for many years rejected the link between smoking and cancer. That is, if one cannot prove beyond a shadow of doubt that an environmental impact is due to drilling, then a link is rejected. This approach by the tobacco companies had a devastating and long-lasting effect on public health from which we have still not recovered [7], and we believe that a similar approach to the impacts of gas drilling may have equally negative consequences.

Although reports of petroleum hydrocarbon exposure in humans [8-14], primates [15], and several other species, including ruminants [16-26], horses [27], wildlife [28], and a dog [29], have been cited in the literature, there are few reports on exposure of animals to gas operations, and to our knowledge, no case reports on exposure of humans to hydrocarbon gas operations [30]. Adler et al. [31] observed aspiration pneumonia in sheep following exposure to gas condensate. In another study, Waldner et al. [32] found no association between the productivity of cattle and exposure to a sour gas pipeline leak; while in a longer-term study [33] in cattle, the same group reported associations between sour-gas flaring and increased risk of stillbirth across three of the four years studied, as well as increased risk of calf mortality in one of the years studied. In a study of habitat selection, Sawyer et al. [34] found that mule deer tended to move away from areas of gas development, and in a recent report [35] from the same author, the deer population dropped by 45 percent in one year, and the survival rate decreased.

Just as epidemiologic studies linked smoking to human health impacts, such studies could be used to assess the health impacts of gas drilling operations on human beings. Studies in laboratory animals have also been a powerful tool for linking components of tobacco smoke to cancer, not only because controlled studies can be done but also because breeding cycles are short and the age at which cancer develops is within a range accessible to laboratory studies. Though such controlled animal studies of the effects of gas drilling are not feasible, animals can nevertheless serve as sentinels for human health impacts. Animals, particularly livestock, remain in a confined area and, in some cases, are continually exposed to an environmental threat. Further, effects on reproduction can be more readily assessed in a herd of cattle than in a human population, simply due to the higher rates of reproduction.

For the past year, we have been documenting cases of animal and owner health problems with potential links to gas drilling. Many cases are currently in litigation. To protect individuals' privacy and due to ongoing legal action, the discussion will not include personal identifying information. We summarize the results of our investigation, provide several case studies, and conclude with recommendations for minimizing or preventing similar problems in the future. This study is not an epidemiologic analysis of the health effects of gas drilling, which could proceed to some extent without knowledge of the details of the complex mixtures of toxicants involved. It is also not a study of the health impacts of specific chemical exposures related to gas drilling, since the necessary information cannot be obtained due to the lack of testing, lack of full disclosure of the International Union of Pure and Applied Chemistry (IUPAC) names and Chemical Abstracts Service (CAS) numbers of the chemicals used, and the industry's use of nondisclosure agreements. Nevertheless, the value of this study is twofold. First, clear health risks are present in gas drilling operations. These cannot be eliminated but can be decreased by commonsense reforms. Second, our study illustrates not only several possible links between gas drilling and negative health effects, but also the difficulties associated with conducting careful studies of such a link. Again, simple commonsense policy reforms could facilitate the collection of data that would lead to a careful assessment of the health consequences of gas drilling on both humans and animals.

SUMMARY OF THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND ANIMAL OWNERS

To describe how exposures may occur, and to report health effects, we conducted interviews with animal owners in six states (Colorado, Louisiana, New York, Ohio, Pennsylvania, Texas) affected by gas drilling. In all but one case, we spoke directly with animal owners. The exception was a case that had previously been documented by the state environmental regulatory agency [36]. When possible, we interviewed the owners' veterinarians. Where available, we have obtained the results of water, soil, and air testing as well as the results of laboratory tests on affected animals and their owners. Documentation was obtained from the animal owners, the veterinarians (with permission of the owners), drilling company representatives, state regulatory agencies, and a Freedom of Information Act (FOIA) request from the Pennsylvania Department of Agriculture. Cases were identified by requesting referrals from environmental groups and individuals actively involved in influencing shale gas policy and studying its effects. For each case, a standard series of questions was asked, including the exact location of each owner's property; details on wells in the area (subsequently verified by crosschecking with state records and, using software developed for this project, mapping the wells relative to the owner's property); details of seismic testing and well flaring; location of wastewater impoundments; results of water, soil, and air testing; details of animal husbandry and medical records preceding, during and following drilling, depending upon the individual case; a list of animals (species, breed, age, sex, use (e.g., livestock)), sorted into those healthy and those unhealthy; health history for all animals; observations of wildlife in the area; and health histories of the humans living in the household. As each case is different, the standard form was used as a starting point, with additional information invariably supplied by individuals being interviewed.

More than one-third of the cases involved conventional wells (shallow or deep vertical wells), with the remainder comprising horizontal wells subjected to high-volume hydraulic fracturing. Because of the scale of the horizontal well drilling operations, such wells were more commonly associated with animal health problems. However, conventional wells have also had problems associated with faulty well casings and failure of blowout preventers; in our study, wastewater dumping and leakage, failure of a blowout preventer, and affected well water involving conventional gas wells were associated with both animal and human health problems.

By the standards of a controlled experiment, this is an imperfect study, as one variable could not be changed while holding all others constant. It also is not a systematic study that will provide the percentage of farms with problems associated with gas drilling, but the design is such that the study can illustrate what can happen in areas experiencing extensive gas drilling. It is also possible to observe temporal correlations between events such as well flaring and air quality, or hydraulic fracturing and water quality leading to toxicity. In two cases, spatial differences (cows in a single herd, with some allowed access to a creek or pond and others not allowed access) could be used to compare outcomes.

Table 1 summarizes the types of wells involved and the sources of exposure, and Table 2 describes the details of each individual case. In some cases, exposure was due to accidents or negligence, but at other times, it was a consequence of normal operations. Direct exposure to hydraulic fracturing fluid occurred in two cases: in one, a worker shut down a chemical blender during the fracturing

Table 1. Number of Cases, by Type of Gas Well and Source of Exposure[a]

Type of gas well	
Shallow vertical wells	4
Deep vertical wells	3
Horizontal high-volume hydraulically fractured wells	18
Source of exposure	
Hydraulic fracturing fluid spill from holding tank	2
Drilling fluids overran well pad during blow out	1
Storm water run-off from well pad to property	3
Wastewater impoundment leak	1
Wastewater impoundment allegedly compromised	1
Wastewater spread on road	2
Wastewater dumped on property	1
Wastewater dumped into creek	3
Wastewater impoundment not contained	3
Well/spring water	17
Pond/creek water	8
Pipeline leak	1
Compressor station malfunction	2
Flaring of well	3

[a]Total number of cases is 24; one case has two types of wells.

Table 2. Summary of Individual Cases

Case	Type of gas well[a]	Source	Animal	Health impact
1	SV	Wastewater dumped on property and into creek	White-tailed deer	Body condition
2	SV	Well/spring water	Bovine	Reproduction, milk production
3	SV	Well/spring water Pond/creek water Drilling fluids overran well pad during blowout	Bovine	Reproduction
4	SV	Well/spring water Pond/creek water Wastewater impoundment allegedly compromised	Bovine Fish	Reproduction, growth Sudden death
5	DV	Well/spring water Pond/creek water	Equine Canine Human	Neurological Urological, gastrointestinal, dermatological Upper respiratory, burning of eyes, headache, gastrointestinal, dermatological
6	DV	Pond/creek water	Bovine	Reproduction
7	DV, HHV	Well/spring water	Canine Poultry Human	Reproduction, dermatological Sudden death, musculoskeletal, dermatological Upper respiratory, burning of eyes, neurological, gastrointestinal, headache
8	HHV	Well/spring water Pond/creek water Wastewater impoundment not contained Wastewater dumped into creek	Song birds Human	Sudden death Neurological, immunological
9	HHV	Pond/creek water Storm water runoff from well pad	Fish	Sudden death

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
10	HHV	Well/spring water	Ovine	Reproduction
		Wastewater impoundment not contained	Canine	Sudden death
			Human	Gastrointestinal, neurological, upper respiratory, burning of eyes, dermatological, vascular, sensory, headache
11	HHV	Wastewater impoundment leak	Bovine	Reproduction
12	HHV	Storm water runoff from well pad	Canine	Neurological
			Human	Gastrointestinal, headache, dermatological
13	HHV	Well/spring water	Equine	Neurological, gastrointestinal, musculoskeletal, upper respiratory
		Pond/creek water		
		Pipeline leak		
			Canine	Urological, gastrointestinal, musculoskeletal, neurological
			Amphibian	Sudden death
			Human	Upper respiratory, burning of eyes, bone marrow
14	HHV	Well/spring water	Canine	Reproduction
		Wastewater spread on road	Human	Neurological
		Wastewater impoundment not contained		
15	HHV	Well/spring water	Canine	Gastrointestinal, dermatological
			Feline	Dermatological
			Human	Gastrointestinal, upper respiratory, burning of eyes, vascular, headache

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
16	HHV	Well/spring water	Llama	Reproduction, upper respiratory
			Human	Endocrine, upper respiratory, burning of eyes, vascular, dermatological, sensory
17	HHV	Well/spring water	Canine	Urological
		Flaring of well	Feline	Gastrointestinal, dermatological
			Human	Upper respiratory, burning of eyes, urological, dermatological, headache
18	HHV	Well/spring water	Ovine	Sudden death
			Poultry	Sudden death
		Storm water runoff from well pad	Human	Vascular, gastrointestinal, headache
		Flaring of well		
19	HHV	Well/spring water	Equine	Reproduction
		Hydraulic fracturing fluid spill from tank	Ovine	Reproduction
			Human	Neurological
		Wastewater dumped into creek		
20	HHV	Compressor station malfunction	Canine	Upper respiratory
		Flaring of well		
			Human	Upper respiratory, burning of eyes
21	HHV	Well/spring water	Bovine	Neurological, reproduction
		Pond/creek water	Equine	Neurological
			Poultry	Sudden death
		Compressor station malfunction	Human	Vascular, immunological
22	HHV	Well/spring water	Ovine	Neurological
			Fish	Dermatological
			Human	Dermatological, gastrointestinal

Table 2. (Cont'd.)

Case	Type of gas well[a]	Source	Animal	Health impact
23	HHV	Well/spring water	Equine	Neurological
		Wastewater spread on road	Canine	Reproduction, gastrointestinal
			Human	Reproduction, upper respiratory, burning of eyes, vascular, sensory, headache
24	HHV	Hydraulic fracturing fluid spill from tank	Bovine	Gastrointestinal, neurological, respiratory, sudden death

[a]SV = shallow vertical well, DV = deep vertical well, HHV = horizontal high-volume hydraulically fractured well.

process, allowing the release of fracturing fluids into an adjacent cow pasture, killing 17 cows in one hour; the other was a result of a defective valve on a fracturing fluid tank, which caused hundreds of barrels of hydraulic fracturing fluid to leak into a pasture where goats were exposed and suffered from reproductive problems over the following two years. Exposure to drilling chemicals occurred during a blowout when liquids ran into a pasture and pond where bred cows were grazing; most of the cows later produced stillborn calves with congenital defects. Exposure to wastewater occurred through leakage or improper fencing of impoundments, alleged compromise of a liner in an impoundment to drain fluid, direct application of the wastewater to roads, and dumping of the wastewater on creeks and land. The most common exposure by far was to affected water wells and/or springs; the next most common exposure was to affected ponds or creeks. Finally, exposures also were associated with compressor station malfunction, pipeline leaks, and well flaring. In addition to humans, the animals affected were: cows, horses, goats, llamas, chickens, dogs, cats, and koi. Other than photographing and recording the presence of dead and dying wildlife (deer, songbirds, fish, salamanders, and frogs) in the vicinity of affected pastures, creeks and ponds, the effect on wildlife has not been well documented.

Because production animals were exposed to the environment for longer periods and in greater numbers than companion animals, and because most of the farms we documented raised beef cattle, cows were represented to a greater extent than other animals. Exposures through well water, ponds, springs, dumping of wastewater into creeks, and spills or leakage of wastewater from impoundments were believed by farmers to result in deaths over time periods typically ranging from one to three days, with cows going down and unable to rise despite symptomatic treatment. The most commonly reported symptoms were associated with reproduction. Cattle that have been exposed to wastewater (flowback and/or produced water) or affected well or pond water may have trouble breeding. When bred cows were likewise exposed, farmers reported an increased incidence of stillborn calves with and without congenital abnormalities (cleft palate, white and blue eyes). In each case, farmers reported that in previous years stillborn calves were rare (fewer than one per year). In most cases where diagnostics were pursued, no final diagnosis was made; in other cases, acute liver or kidney failure was most commonly found. Of the seven cattle farms studied in the most detail, 50 percent of the herd, on average, was affected by death and failure of survivors to breed. In one case, exposure to drilling wastewater led to a quarantine of beef cattle and significant uncompensated economic loss to the farmers.

The most dramatic case was the death of 17 cows within one hour from direct exposure to hydraulic fracturing fluid. The final necropsy report listed the most likely cause of death as respiratory failure with circulatory collapse. The hydraulic fracturing fluid contained, among other toxicants, petroleum hydrocarbons and quaternary ammonium compounds (tetramethylammonium and hexamethylenetetramine). Although petroleum hydrocarbons were reported to be found in the small intestine, lesions in the lung, trachea, liver and kidneys suggested exposure to other toxicants as well, and quaternary ammonium compounds have been described as producing similar lesions [37].

Two cases involving beef cattle farms inadvertently provided control and experimental groups. In one case, a creek into which wastewater was allegedly dumped was the source of water for 60 head, with the remaining 36 head in the herd kept in other pastures without access to the creek. Of the 60 head that were exposed to the creek water, 21 died and 16 failed to produce calves the following spring. Of the 36 that were not exposed, no health problems were observed, and only one cow failed to breed. At another farm, 140 head were exposed when the liner of a wastewater impoundment was allegedly slit, as reported by the farmer, and the fluid drained into the pasture and the pond used as a source of water for the cows. Of those 140 head exposed to the wastewater, approximately 70 died and there was a high incidence of stillborn and stunted calves. The remainder of the herd (60 head) was held in another pasture and did not have access to the wastewater; they showed no health or growth problems. These cases approach the design of a controlled experiment, and strongly implicate wastewater exposure in the death, failure to breed, and reduced growth rate of cattle.

Companion animals were defined as those animals that were kept as pets, and included horses, dogs, cats, llamas, goats, and koi. Companion animal exposures typically occurred when animals ingested affected water from a well, spring, creek or pond. Reproductive problems (irregular cycles, failure to breed, abortions, and stillbirths) and neurological problems (seizures, incoordination, ataxia) were the most commonly reported. Other commonly reported symptoms included those of gastrointestinal (vomiting, diarrhea) and dermatological (hair and feather loss, rashes) origin.

In the majority of cases, owners of animals were exposed upon using their well or spring water for drinking, cooking, showering and bathing. Upper respiratory symptoms (including burning of the nose and throat) and burning of the eyes were the most commonly reported. Headaches and symptoms associated with the gastrointestinal (vomiting, diarrhea), dermatological (rashes), and vascular (nosebleeds) systems were commonly reported.

CASES ILLUSTRATING THE EFFECTS OF GAS DRILLING ON PRODUCTION AND COMPANION ANIMALS AND THEIR OWNERS

Case 1

Two homes (A and B) are located within two miles of approximately 25 shale gas wells. The closest pad, drilling muds pit, and wastewater impoundment are within one mile of both homes; the impoundment is approximately 4.5 acres in area and is at a higher elevation than either home. Two compressor stations are located within one mile of both homes. The owners have a variety of companion and farm animals, and reported no unusual pet morbidity or mortality preceding drilling operations. Predrilling tests on water sources were not done for either home. Soon after drilling began, the owner of Home B noted that her well water had an odor and black sediment, and the owners of Home A observed a decreased quantity of their water sources (a well and a spring). Once the wastewater impoundment was constructed, the owners of Home A noted a dramatic decrease in quantity, as well as poor quality, of both the well and spring water. The spring served as the sole source of water for the owners' farm animals. Approximately nine months after drilling began, the owners of Home A began hauling water from a nearby creek, to supplement the spring water.

Since drilling operations began, both owners have observed wastewater being spread on the roads during all weather conditions, and noted that cats and dogs in their neighborhood licked their paws after walking on the road, and also drank from wastewater puddles; some of these animals became severely ill and died over a period of one to three days following these exposures. According to the owner of Home B, the wastewater impoundment was not initially fenced and animals had direct access to the wastewater. An accident involving the wastewater impoundment was noted by both owners; after filling, a truck carrying wastewater drove away from the impoundment site with an open valve, releasing approximately 20 gallons of wastewater onto the impoundment access road and onto the road near the property of Home A. Most recently, both the drilling company and the state environmental regulatory agency were notified of a spill from the wastewater impoundment that flowed past temporary barriers and into a creek; based on soil erosion patterns, the owners of Homes A and B reported that this spill had been ongoing for months. Soon after this accident, a malfunction occurred in the wastewater impoundment aeration system, producing a raw sewage smell that persisted in the air around Homes A and B for days and sickened the families in both homes. When the owner of Home A complained, the drilling company offered to pay motel expenses for her and her family; this offer was declined because the owner refused to leave her animals.

Approximately a year after drilling began, an 18-year-old intact female American Quarter Horse in Home A had an acute onset of anorexia, malaise, rapid weight loss, and mild incoordination after testing normal on a physical examination a few weeks earlier. The horse was treated symptomatically with an antibiotic, steroid, and antihistamine. A few days later, the horse had become ataxic, and was treated for equine protozoal myeloencephalitis, although no diagnosis was made. The horse did not improve after three to four days and was treated again. Within a few days, the horse's neurological symptoms had progressed such that the horse was unable to rise. Blood and clinical chemistry parameters indicated acute liver failure due to toxicity. The veterinarian suspected heavy metal poisoning as a cause of the horse's sudden illness; this was not confirmed, as toxicology tests were not done. The horse was euthanized two weeks after onset due to poor prognosis and failure to respond. Similar neurologic signs were reported in another case in this study that involved two horses living adjacent to a deep, vertical gas well operation.

In addition, both homeowners were caring for animals that were bred at this time: the owner of Home B had a three-year-old intact female Boer goat that aborted two kids in the second trimester, and the owners of Home A had a five-year-old intact female Boxer that experienced dystocia with a fourth litter (after previously whelping three normal litters), producing one stillborn pup and one pup with cleft palate that died soon after birth. This same dog subsequently whelped a fifth litter of 15 pups in which seven pups were stillborn and eight pups died within 24 hours. All the pups were afflicted with congenital hypotrichosis; that is, they were born with the complete or partial absence of normal hair.

Soon after drilling and hydraulic fracturing began for the first well, a child living in Home B began showing signs of fatigue, severe abdominal pain, sore throat, and backache. Six months later, the child was hospitalized with confusion and delirium and was given morphine for abdominal pain. After the deaths of several animals as cited above, the child's physician suspected that the child's symptoms were of toxicological origin. A toxicology test revealed arsenic poisoning as the cause of the child's sickness. The family stopped using their well water despite test results indicating that the water was safe to drink, and the child gradually recovered after losing one year of school.

During high-volume hydraulic fracturing, substances that occur naturally in the shale, including arsenic, come to the surface in wastewater. In this case, the wastewater was stored in the impoundment, where aerators misted the chemicals into the air, increasing the chances of inhalation by animals and people; also, surface spillage of wastewater, as noted above, could have contaminated the ground water. Tests on well water from both Homes A and B, and the spring from Home A, did not show elevated levels of arsenic; however, it is possible that, given fluctuations in the water table and water quality, high levels of arsenic may have initiated symptoms in the child in Home B and then dropped to low levels before water testing was done more than one year later. Also, reported arsenic levels may be deceptively low because arsenic can be converted to arsine-a toxic gas that dissipates rapidly [38]. In people, both acute and chronic oral exposure to inorganic arsenic causes gastrointestinal effects as well as effects on the nervous system: short-term effects include headaches, weakness, and delirium, while long-term effects include peripheral neuropathy [39]. Acute exposure of people to arsine can produce many effects including abdominal pain and headaches [39]. Animals exposed acutely to inorganic arsenic may show many symptoms including staggering gait, extreme lethargy, and intense abdominal pain, while animals exposed over a longer period of time may manifest signs including anorexia, depression, and partial paralysis of the rear limbs [40]. Animal studies show that arsenic can also cause fetal malformations and fetal death [41].

As the family in Home B continued to be screened for toxicants, random urine tests on all family members were positive for phenol, a metabolite of benzene, with dramatic increases over a period of a few months. Based on occupational health studies [e.g., 42], the testing laboratory judged these results to be consistent with chronic exposure to 0.5 to 4.0 ppm benzene in the air. The most recent symptoms observed by families in both homes include extreme fatigue, headaches, nosebleeds, rashes, and sensory deficits (smell and hearing). The child in Home B also had difficulty breathing, and again had to be taken out of school. Doctors of the families in both homes warned them to leave their homes for at least 30 days or suffer more severe health consequences. The owner of Home B followed her doctor's advice, and moved her children out of her home, returning each day to care for her animals; the owners of Home A elected to remain at their home to care for their animals. After one month of being away, the phenol levels as well as the symptoms of the children in Home B decreased, while the owner of Home B, who returns to the home for a few hours each day, has increased phenol levels and worsening of symptoms. One of the owners in Home A, who works at home, has experienced worsening of symptoms.

This case illustrates the importance of considering both animal and human health. Animals live among us and are exposed to the same environmental influences; however, they tend to suffer more direct exposure and have shorter life and reproductive cycles. If it were not for the numerous deaths of animals soon after shale gas operations began in this neighborhood, the child's doctor might not have ordered toxicology tests, as arsenic poisoning is not a common diagnosis.

Case 2

In this case, a beef cattle farmer had a herd of 96 cattle (Angus Limousine cross) that was divided among three pastures. The farm is located in an area of intensive gas drilling, with two active shallow vertical gas wells on the farmer's property and approximately 190 active gas wells within five miles of the property; of these, approximately 11 are shale gas wells and approximately 26 are deep vertical gas wells. In one pasture, 60 cows (a mixed herd, mostly 5- to 10-year-old bred cows) had access to a creek as a source of water. In a second pasture, 20 cows (bred yearlings) obtained water from hillside runoff, and in a third pasture, 14 feeder calves (8 to 14 months old) and two bulls had access to a pond. Over a three-month period, 21 head from the creek-side pasture died (17 adult bred cows and 4 calves). All the cattle were healthy before this episode. Despite symptomatic treatment, deaths occurred 1 to 3 days after the cows went down and were unable to rise. Basic diagnostics were done, but no cause of death was determined. On rendering, 16 of the 17 adults were found to have dead fetuses, nearly doubling this farmer's losses. Of the 39 cows on the creek-side pasture that survived, 16 failed to breed and several cows produced stillborn calves with white and blue eyes. The health of the cattle on the other two pastures was unaffected; on the second pasture, only one cow failed to breed. Historically, the health of the herd was good, the farmer reporting average losses of 1-2 cows a year in his herd of nearly 100 cattle.

This is an interesting case because it has a natural control group. That is, the cattle that were kept along the creek suffered severe problems while the cattle in pastures at a higher elevation and away from the creek experienced no morbidity or mortality. As discussed below, the contamination of the creek may have been caused by illegal dumping of wastewater. Fortunately, these cows were not taken to slaughter, as they died on the farm. However, they still may have entered our food chain as well as that of our pets: rendering plants produce feed for many non-ruminants including chickens, pigs, cats, dogs and horses, so it is possible that chickens, raised for egg production or meat, and pigs were fed the flesh from these cattle.

Case 3

This case concerns farmers that have raised beef cattle (Herford Simmental cross) for the past 21 years. Before drilling operations began the farmers lost one or two animals out of a closed herd of 33 (yearlings, heifers, mature cows, two bulls) every few years to illness or accident. There is one active shale gas well on the farmers' 530-acre property, and approximately six active shale gas wells within two miles of their property. A private well provides water for the family's use; the water for the herd comes from a creek that originates from springs above and below the well pad, and spillover from a pond below the well pad. The gas wellhead is 300 feet from the farmers' house and 250 feet from their water well. The well pad is 75 feet from their barn at higher elevation, and slopes directly down to the door. A one-acre impoundment, used to collect wastewater from the high-volume hydraulic fracturing operations, and a 1/3-acre drilling muds pit, used to collect the chemicals and fluids brought to the surface during drilling operations, were both within 350 feet of the farmers' water well, and within 200 feet of the creek and the pond where the cattle drink.

Soon after hydraulic fracturing operations concluded, the farmers noticed that on the far bank of the wastewater impoundment, two dark spots could be seen adjacent to a 20-acre cow pasture. According to the farmers, these two spots were a concern as they grew in size from day to day; approximately one month after first observing these spots, the farmers found ankle-deep water in one-third of an acre of the pasture with the wet area extending another one-quarter of an acre into the pasture; the pasture grass in these areas appeared to be burned. Fearing their herd drank the wastewater, they voluntarily quarantined their farm and notified the state environmental regulatory agency.

According to the farmers, drilling company workers informed them that the liners of both the wastewater impoundment and the drilling muds pit had two-foot tears, and that the tear in the liner of the wastewater impoundment had caused the leak into the cow pasture. Except for the two bulls, the entire herd was exposed to the wastewater leakage.

Four notices of violations were issued to the drilling company by the state environmental regulatory agency: failure to notify the agency, improperly lined impoundment (pressure testing of liner revealed a failed patch), pollution of a spring and farm pond due to leakage of the impoundment, and mismanagement of residual waste (wastewater leaked from the impoundment onto the ground and surfaced in an adjacent pasture).

Testing of the wastewater in the impoundment indicated the presence of calcium, iron, magnesium, manganese, potassium, sodium, strontium, fluoride, chloride, sulfate, and bromide; there was no reported testing for any organic compounds. Strontium was of most concern: it can be toxic to both animals and people because it replaces calcium in bone, especially in the young, and because it may take years to be eliminated from the body [43]. The state environmental regulatory agency placed a quarantine on the herd such that mature cows would be held from slaughter for six months, yearlings would be held for nine months, calves exposed in utero would be held for eight months, and growing calves would be held for two years. Six of the exposed cows eventually went on to slaughter, and, according to the farmers, there was no testing before or after slaughter.

Pre-drilling tests were not done on any of the cattle’s sources of water; post-drilling tests were done and revealed no significant findings. Soil tests done on the cow pasture contaminated by the leaked wastewater revealed high levels of chloride, sulfate, sodium, and strontium when compared to background samples. The liners from both the wastewater impoundment and drilling-muds pit were removed, the affected soil removed, and areas remediated; sulfate concentrations remained at high levels in the cow pasture despite remediation.

During the spring of the first calving season following the leakage of wastewater into their cow pasture, the farmers lost two calves: one calf was aborted late-term, and the other calf lived for approximately seven days before dying [44]; both calves were exposed in utero to the wastewater. In the second calving season post-drilling, the farmers lost 11 out of 17 calves: seven were stillborn, three died a few months after birth and one was born alive but severely ill; the dams of all the calves had previously been exposed to the wastewater. The severely ill calf and a stillborn calf were sent for necropsy: the ill calf was diagnosed with *E. coli* septicemia, and the stillborn calf was diagnosed with goiter (diffuse thyroid hyperplasia); both calves were also diagnosed with low liver vitamin E and selenium.

This case illustrates several important points. First, the testing was not complete. According to the farmers, they were not informed of the chemicals used during either drilling or hydraulic fracturing operations. Testing of the water well and cattle's sources of water excluded organic compounds except for a pasture spring; the wastewater analysis also excluded organic compounds. No toxicology tests were done on live cattle, and the tests at necropsy omitted volatile organic compounds, endocrine disruptors, and many minerals present in the wastewater. The cattle's sources of water were tested only after the farmers lost many calves. Soil tests were not done in the area affected by the leakage of the drilling-muds pit. Second, the cattle were exposed to sulfate in the wastewater for at least one month and to elevated sulfate in the grass and soil [45, 46] for over a year. Studies show that increasing dietary sulfur decreases the bioavailability of selenium [47-50], and that Vitamin E and selenium deficiency is associated with reproductive failure in cattle [51, 52]. Third, the liner tear and subsequent leakage of drilling fluids onto the farmers' land were not considered a potential problem and not officially recorded as a violation by the state environmental regulatory agency. Due to gas drilling operations on their property, the farmers now have 26 head of cattle instead of 33, and have lost 40 to 50 acres of hayfields. These farmers received no compensation from the drilling company for the loss of their animals, damage to their land, or the treatment of the animal health problems they have encountered since gas drilling began.

DISCUSSION

The most striking finding of our investigations was the difficulty in obtaining definitive information on the link between hydrocarbon gas drilling and health effects. However, the results point to a number of ways policies can be changed to facilitate better data collection and to avoid obvious risks to animal and human health.

Practices for Providing Better Assessment of Health Impacts

Nondisclosure Agreements

Nondisclosure agreements between injured parties and corporations make it difficult to document incidents of contamination. Compensation in the form of cash, payment for all settlement expenses, an offer to buy the property and/or payment for medical expenses in exchange for a nondisclosure agreement prevents information on contamination episodes and health effects from being documented and analyzed. Nondisclosure agreements are common in all areas of business and are often essential to protect intellectual property. However, when documentation of health problems associated with gas operations is shielded from public scrutiny by a nondisclosure agreement, this is clearly a misuse of this important business tool and should be prohibited. Likewise the lack of prior testing of air and water, and of follow-up testing during drilling and after incidents of suspected contamination, impedes the analysis of health impacts. Even when testing is done, the results are being withheld from interested parties either by government agencies (e.g., by incomplete responses to FOIA requests) or by the industry. If the industry, government agencies, and the public truly want the facts, then appropriate testing must be done, and full disclosure of all data associated with both baseline and incidents of suspected contamination must be made. Without full disclosure of all facts, scientific studies cannot properly be done. Science should drive decisions on whether or not to use a practice such as shale gas drilling, and until scientific studies can proceed unimpeded, then an accurate assessment cannot be made.

Food Safety

A major problem is the lack of federal funding for food safety research. We documented cases where food-producing animals exposed to chemical contaminants have not been tested before slaughter and where farms in areas testing positive for air and/or water contamination are still producing dairy and meat products for human consumption without testing of the animals or the products. Some of these chemicals could appear in milk and meat products made from these animals. In Case 3, a quarantine was instituted after cattle were exposed to wastewater. However, basic knowledge, such as hold times for animals exposed to chemical contaminants as a result of gas operations, is lacking, and research in this area is desperately needed to maintain an adequate level of food safety in our country [53]. Without this information, contaminants in the water, soil and air from gas drilling operations could taint meat products made from these animals, thus compromising the safety of the food supply.

Routes of Exposure

The major route of exposure in the cases documented here is through water contamination. This is perhaps the most obvious problem (seen in all three case studies), but other routes of exposure are of serious concern. Soil contamination can be significant in situations such as that described in Case 3. Although the cases we have documented thus far include only a handful of exposures through affected air, the actual incidence of health effects may be underestimated due to a lack of air sampling. In Case 1, toxicological testing suggested high levels of ambient benzene due to a nearby impoundment pond, but air canister tests were not done at the time. Neither drilling companies nor state environmental regulatory agencies routinely offer air canister tests as a part of testing protocols, and due to the expense, many property owners are reluctant to pursue them on their own. Nevertheless, the effects of air pollution on cardiovascular and respiratory health have been well documented [54], and we believe that exposure to contaminated air may contribute significantly to the health problems of both people and animals living near gas drilling operations. In several cases where air monitoring was done, the results confirmed the presence of carcinogens commonly known to originate from gas industrial processes such as exploration, drilling, flaring, and compression. Thus, the Environmental Protection Agency (EPA) must include a study of air in its congressionally mandated hydraulic fracturing study [55] if it is to be complete.

Testing

The most important requirement for an assessment of the impact of gas drilling on animal and human health is complete testing of air and water prior to drilling and at regular intervals after drilling has commenced. This includes chemicals used in the drilling muds, fracturing fluid and wastewater (the latter contains heavy metals and radioactive compounds normally found in a particular shale [56]). Currently, the extent of testing (particularly for organic compounds) is frequently inadequate and limited by lack of information on what substances were used during the drilling process. In a number of the cases that we have studied, drinking water is clearly unsuitable for human and animal consumption, based not only on the smell and turbidity, but also on pathological reactions to drinking the water. Nevertheless, because of inadequate testing, the water is deemed fit for consumption and use, and neither bottled water nor the large plastic containers known as "water buffaloes" are typically provided for the affected individuals-and even less commonly for animals living on those farms. In Case 1, water was reluctantly provided for the humans (after considerable effort) but not to the animals living on the farm. Even when identified, the health effects of chemicals associated with the drilling process are unknown in many cases. No Maximum Contaminant Levels (MCLs) have been set by the EPA for many of the compounds used, and those that have been set are based on older data that does not take into consideration effects at significantly lower concentrations (e.g., endocrine disruption [5]). Furthermore, the disclosure of all chemicals involved in the drilling and hydraulic fracturing processes is not required if a component can be justified as a "trade secret." In order to be complete, air, soil and all sources of potable water used for humans and animals in the vicinity of a well site (at least within 3,000 feet for soil and water tests [57], and five miles for air monitoring, based on dispersion modeling of emissions from compressor stations [58]) must be tested for all components that are involved in drilling and are likely to be found in wastewater, before any work on the site commences. Sampling must then be repeated at intervals following the commencement of drilling as well as upon suspicion of adverse effects. The following practices must be part of a testing protocol:

1. The sampling must be done by a disinterested third party with a clear chain of custody between sampling and testing. A certified independent laboratory must do the testing, and the results must be available to all interested parties.
2. All chemicals (with IUPAC names and CAS numbers) used in the hydraulic fracturing fluid at any concentration for each well must be disclosed to the property owners within a five-mile radius, testing laboratories, local governments, and state agencies. Material Safety Data Sheets (MSDSs) for each chemical and chemical mixture must accompany this disclosure. Following this procedure will allow prior testing to be targeted to specific chemicals to be used in the drilling process for a specific well, as well as providing valuable information to first responders and hospital personnel in the case of an accident.
3. Upon suspicion of adverse health effects, testing must include air, soil, wastewater, all sources of drinking water, and blood, urine and tissue samples from affected animals and humans. If methane is present in drinking water, isotopic analysis to determine the origin (thermogenic vs. biogenic) must be done.
4. As illustrated by several cases we documented, air canister tests are essential. This must be done as a baseline before drilling begins and during and after well flaring. It must also be done after a wastewater impoundment and a compressor station have been established.
5. Any fracturing fluid chemicals and chemicals released from the shale that are known or possible human carcinogens, are regulated under the Safe Drinking Water Act, or are listed as hazardous air pollutants under the Clean Air Act must have MCLs, which are set by the EPA. Many of the chemicals to which both people and animals are exposed as a result of high-volume hydraulic fracturing are not listed as primary contaminants, and thus have no enforceable MCL. More than half of the chemicals listed as toxic chemicals in a recently released U.S. House of Representatives report [59] have no MCL.

6. All testing expenses must be a part of the cost of doing business for gas drilling companies.

Testing before and during drilling operations is an important part of documenting health effects. If health effects are related to a chemical pre-existing in a pond or well, this would prevent a false association between drilling and water contamination. Alternatively, if a change in chemical composition is correlated to health changes, then a strong justification for compensation is provided. In numerous cases that we documented, compensation was not provided because adequate prior testing had not been done. By doing complete testing, at the proper times, a clear scientific justification can be made for providing or denying compensation. Beyond that, a better understanding of what practices lead to water contamination can be obtained. This will be a benefit to people living in the midst of shale gas drilling and will, in fact, benefit the industry by providing consistent and useful data to guide operations. The current practice of under-testing and denying any link between drilling and water, air, or soil contamination is beneficial to neither the public nor the industry.

Practices for Avoiding Animal and Human Exposure to Environmental Toxicants

As shale gas drilling expands across the northeastern United States, exposure of animals and humans to environmental toxicants can result from negligence, illegal actions, catastrophic accidents (at drilling pads or compressor stations), or normal operations. Negligence and illegal actions are difficult to prevent and may have contributed to the health problems we documented. Suspected illegal dumping of wastewater and the alleged compromise of the liner of a wastewater impoundment were most likely responsible for cattle deaths in two instances that we studied. Cases of alleged wrongdoing [60] illustrate the vulnerability of agricultural operations in the midst of large volumes of toxic waste. Dumping and other intentional violations are difficult to prevent or regulate given the large numbers of small companies involved in servicing drilling operations and the lack of willingness and funding on the part of state environmental regulatory agencies to investigate and fine the gas industry. The prevalence of small subcontractors increases the possibility that best practices will not be followed due to inadequate training and supervision.

Although accidents might be minimized with strict safety standards and careful inspection, regulatory agencies would require sufficient staff to monitor operations. This is obviously not the case in Pennsylvania, where 666 environmental health and safety violations have been reported in 2011 as of June [61]. With a staff of 37 inspectors [62] and 64,939 active wells (as of December, 2010), regulatory oversight is essentially impossible. The situation is even worse in New York State, where only 16 inspectors are currently on the staff of the Department of Environmental Conservation. Although the number of staff positions required to police this industry adequately would necessarily be very large, hiring of new inspectors is essential if environmental and health damages are to be minimized. New York, Pennsylvania, and Iowa are the only active drilling states that have no severance tax for drilling operations. A severance tax could fund additional inspectors and help insure compliance with existing regulations, although this will require the political will to levy a tax sufficient to fund the required number of inspectors. Given the high probability that accidents will happen [63], increasing setbacks between homes, barns, schools, ponds, and streams would provide some additional security. The current regulation in Pennsylvania is a setback of 200 feet from water supply springs and wells, 100 feet from surface water bodies, and 200 feet from wetlands. The revised draft supplemental generic environmental impact statement in New York indicates a 500-foot setback from private water wells. Increasing these setbacks 5- to 10-fold would decrease but not eliminate the impacts of accidents such as the April 20, 2011 spill in Bradford County, PA [64]. Contamination of the air by compressor station blowouts and contamination of streams leave an imprint that cannot be easily mitigated by even the most stringent setbacks.

Normal practices can be modified to reduce but not eliminate exposure of humans and animals to toxicants associated with gas drilling. One of the important problems associated with shale gas drilling is the huge volume of wastewater generated. This wastewater, which includes flowback and produced water, contains at different times in the process the chemicals used in the hydraulic fracturing fluid as well as compounds and minerals extracted in the fluid flowing back with hydrocarbon gas. The materials extracted from underground can be equally or more toxic than the hydraulic fracturing fluid, and include radioactive material (e.g., radium-226, radon-222, and uranium-238), arsenic, lead, strontium, barium, benzene, chromium and 4-nitroquinoline-1-oxide [56]. However, despite the actual toxicity of this material, according to the EPA, "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of . . . natural gas" are considered "solid wastes which are not hazardous wastes" [65]. This allows the substances to be spread on roads as deicing solutions and as solutions to minimize dust and sets up a potentially lethal threat, particularly to companion animals, wildlife, and children. Typically these solutions contain high salt concentrations and attract dogs and cats, as was illustrated in Case 1. This hazard can be easily mitigated by not allowing wastewater to be spread or sprayed on roads.

Before wastewater is removed from a drilling site, it is often stored in large impoundments (sometimes serving multiple well pads) where the volume is decreased by evaporation. This increases the concentration of some toxic substances in the impoundment (salts, heavy metals) and also introduces other toxicants into the atmosphere (e.g., volatile organics such as benzene and toluene). In addition, impoundments are associated with a number of deaths of both cattle and wildlife [66]. These effects raise the question of whether wastewater should be stored in open impoundments. Whereas this may be economically advantageous to the drilling company, the environmental and agricultural impacts are too great to allow this practice to continue. In Pennsylvania, some progress has been made in recycling increasing fractions of the wastewater. This decreases the total volume of wastewater but increases its toxicity due to the successive increase in the concentrations of total dissolved solids. The alternative is to store wastewater in metal containers at the drilling site before it is removed for disposal.

Finally, the disposal of wastewater presents significant environmental risks. Cases of alleged dumping of untreated wastewater in streams have been documented in the press (e.g., [60]). In the southwestern United States, wastewater is disposed of in injection wells; however, the prevalence of nonporous sandstones and shales in Pennsylvania and New York State largely precludes the use of disposal wells. An earthquake of magnitude 3.2 was associated with injection into a hydraulically fractured vertical well on February 3, 2001 near Avoca, New York [67], suggesting that seismic considerations may further limit the development of injection wells in New York State. Similar seismic occurrences in other parts of the country, most recently in Ohio [68], may mean that New York and Pennsylvania will have fewer options for disposal of wastewater due to shale gas drilling. In May 2011, a voluntary moratorium was placed on the acceptance of hydraulic fracturing wastewater at sewage treatment plants in Pennsylvania. These plants are not equipped to handle either the radioactive and toxic compounds or the high salt content of this waste, and the increased use of recycling has magnified the problem. Discharge of water treatment plants into the Monongahela River led to the contamination of drinking water in Pittsburgh in 2010 [63]. Sewage treatment plants clearly are not a viable option for disposal of wastewater, and despite the industry's progress in recycling, suitable injection wells are unlikely to be located to support the scale of drilling planned in Pennsylvania and possibly New York State.

CONCLUSION

Animals, especially livestock, are sensitive to the contaminants released into the environment by drilling and by its cumulative impacts. Documentation of cases in six states strongly implicates exposure to gas drilling operations in serious health effects on humans, companion animals, livestock, horses, and wildlife. Although the lack of complete testing of water, air, soil and animal tissues hampers thorough analysis of the connection between gas drilling and health, policy changes could assist in the collection of more complete data sets and also partially mitigate the risk to humans and animals. Without complete studies, given the many apparent adverse impacts on human and animal health, a ban on shale gas drilling is essential for the protection of public health. In states that nevertheless allow this process, the use of commonsense measures to reduce the impact on human and animals must be required in addition to full disclosure and testing of air, water, soil, animals, and humans.

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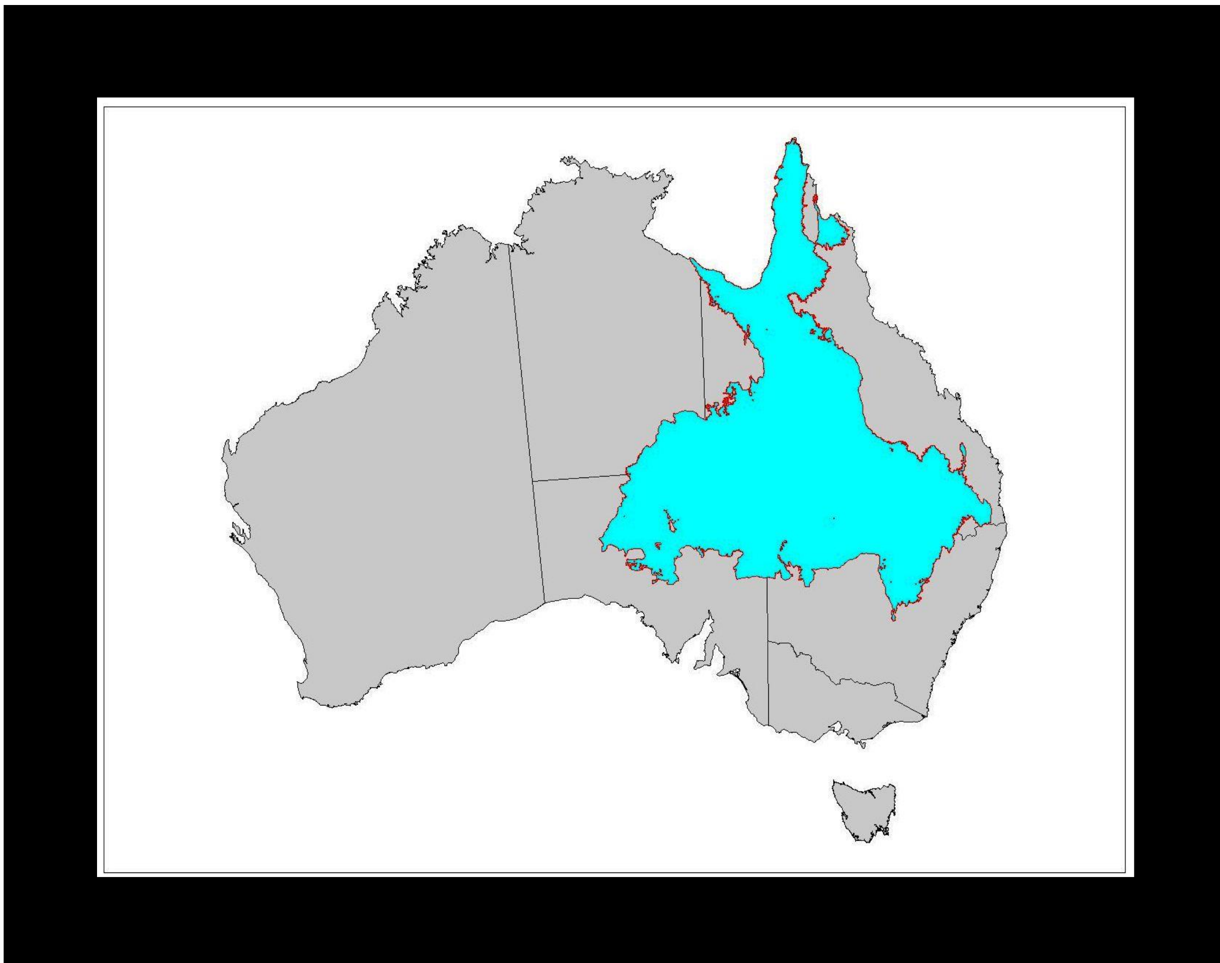
SoilFutures Consulting Pty Ltd

GREAT ARTESIAN BASIN RECHARGE SYSTEMS AND EXTENT OF PETROLEUM AND GAS LEASES

SECOND EDITION

WITH RESPONSE TO MINISTERIAL REVIEW



Prepared for

THE ARTESIAN BORE WATER USERS ASSOCIATION

March 2015

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Preface to Second Edition

The First Edition of this report was presented to the NSW Minster for Water by the NSW Artesian Bore Water Users Association on the 7th November, 2014. One of the immediate criticisms of the document was lack of transparent peer review. In response to this a Revised Edition pas published with clear peer review references and presented to the NSW Minister for Water on 5th December 2014. The Revised Edition was also presented in person to Mr Troy Grant, NSW Deputy Premier in his offices at Dubbo on 19th December, 2014.

The Revised Edition had wide peer review from both Australian and international hydrogeologists, and scientists. It remained substantively unchanged, but incorporates the results of considered critique and some small changes to maps presented. One significant change in the Revised Edition is that recharge of less than 1 mm has been removed as being substantial or critical recharge within the GAB.

Following the publication of the Revised Edition of this document in 2014, a review of the report was presented to the Artesian Bore Water Users Association by Mr Kevin Humphreys, NSW Minister for Water on 14th February, 2015. Whilst this review does have a NSW DPI Office of Water letterhead, it is neither dated, nor signed and no reviewer is named or acknowledged. Nonetheless, in an attempt to clarify matters raised by the NSW Minister for Water, this Second Edition has been prepared with responses to his review given in Appendices 1and 2 of this report.

This Second Edition of the document and its predecessors are not attempts to describe the complete hydrogeology of the Great Artesian Basin (which seems to be a common criticism of the first edition), but represents a mapping exercise using the highest quality peer reviewed CSIRO and State Agency spatial data, as well as reviewing the latest peer reviewed and published reports on recharge and connectivity in the GAB. The technical information from these sources is the culmination of hundreds of person years of patient and thorough research on the GAB by well qualified and recognised scientists. The report draws conclusions based purely on the mapping and the review material.

Executive Summary

The Great Artesian Basin (GAB) of Australia extends over 22% of the Australian continent where it is the only reliable groundwater or surface water source. The GAB contains 65 000 km^3 (or **115 658** Sydney Harbours) of groundwater which is released under pressure to the surface through natural springs and artesian bores across its extent (QDNRM 2012).

Much of the groundwater held in the GAB is very old, having taken thousands to many hundreds of thousands of years to reach its current position in the basin from the recharge beds which are predominantly around the margins of the basin. Modern recharge is not thought to add significantly to the volume stored in the basin however it provides the crucial pressure head to keep the artesian waters flowing to the surface across this massive expanse of land. In most areas, the bulk of the GAB has a recharge value of less than 0.1 mm/yr.

This report is not an exhaustive review of GAB hydrogeology, yet uses the findings of the most recent and valuable recharge measurement and modeling of recharge. State held data on gas, coal seam gas (CSG), and petroleum production and exploration leases are combined to create a GAB wide data set. This report shows that 80% of the GAB currently has a gas, petroleum or CSG exploration or production license over it.

Modern recharge concepts are summarised into maps and overlain with the extent of gas and petroleum production and exploration license areas. 9% of the GAB has recharge greater than 0.1 mm/yr. Less than 6% of the GAB provides recharge which pressurises most of the remainder of the basin with recharge greater than 1 mm/yr. Approximately 2.1% of the total area of the GAB provides than 5 – 30 mm/yr recharge to the basin, and only 0.2% of the GAB provides greater 30 - 80 mm/yr of recharge. These recharge values are recognised as very low, despite being the highest in the basin. These very critical recharge areas are rare and widely separated. The main recharge area in NSW is in the East Pilliga Forest between Narrabri and Coonabarabran.

Using a simple spatial overlay, the main recharge zones (> 1mm/yr) of the GAB which provide pressure to the remainder of the GAB are 69% covered with gas, coal seam gas (CSG) leases. Typically CSG production involves dewatering (pumping) of coal seams to allow methane gas to be extracted (the water is a waste product of production called produced water). There is proven downwards connection between sub basins of the GAB and many of its underlying petrochemical rich basins (Surat has 10% connection; Eromanga has up to 50% connection). It follows that dewatering of aquifers under the GAB where proven connectivity exists can ultimately reduce pressure heads in the critical recharge areas of the GAB and reduce or halt water flow at its numerous bores and springs.

This report shows that the proliferation of gas exploration and production licenses on recharge zones appears to have progressed without much consideration of a GAB wide impact on artesian groundwater resources and pressures. Regulation which is GAB wide and transgresses state boundaries should be considered particularly with regard to protection and management of the few and critical recharge areas of the GAB.

Clearly, there are other wide ranging risks to the water supply of the GAB, with many free flowing bores still in existence (which causes local water and pressure depletion), as well as large scale uranium mining in South Australia. None of these other risks have the potential to stop groundwater flowing across entire sub basins within the GAB.

1. Introduction

1.1 Background

This report has been prepared in response to a request from Mrs Anne Kennedy of the Artesian Bore Water Users Association to provide information on the extent and quality of the recharge areas of the Great Artesian Basin (GAB), and the extent of Coal Seam Gas licenses in relation to the recharge areas. The GAB provides the only reliable water resource for 22% of Australia. The community perception is that there is considerable proliferation of both gas and petroleum exploration and production licenses across the GAB. The potential cumulative GAB wide impact of gas and petroleum extraction and dewatering of aquifers (which is general practice in coal seam gas extraction) in recharge zones is largely unknown.

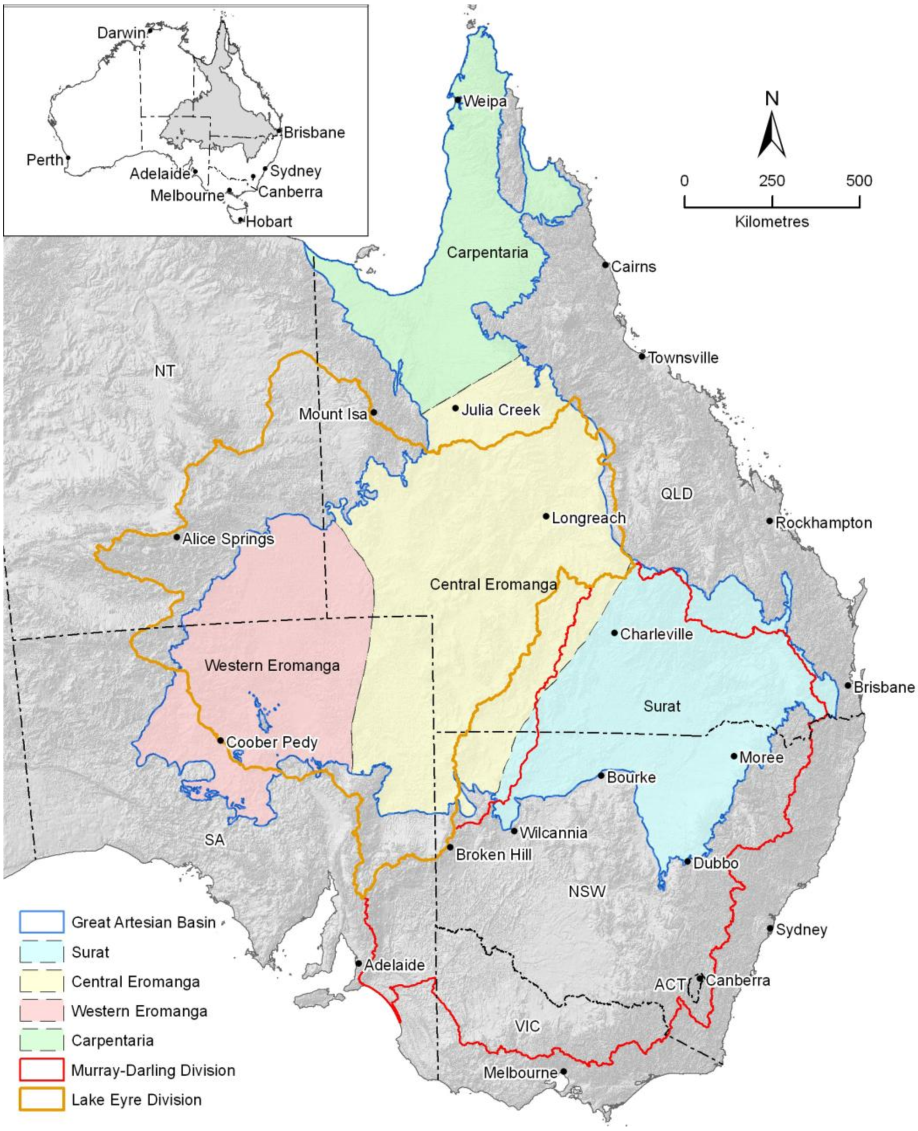

Figure 1: Location of the Great Artesian Basin within Australia

The following description of the Great Artesian Basin (GAB) is given in Ransley and Smerdon (2012).

The GAB contains an extensive and complex groundwater system. It encompasses several geological basins that were deposited at different times in Earth's history, from 200 to 65 million years ago in the Jurassic and Cretaceous periods. These geological basins sit on top of deeper, older geological basins and in turn, have newer surface drainage divisions situated on top of them (e.g. the Lake Eyre and Murray-Darling river basins). In this context – as a groundwater basin – the GAB is a vast groundwater entity underlying one-fifth of Australia.

Discharge from the GAB aquifers occurs naturally in the form of concentrated outflow from artesian springs, vertical diffuse leakage from the Lower Cretaceous-Jurassic aquifers towards the Cretaceous aquifers and upwards to the regional watertable and as artificial discharge by means of free or controlled artesian flow and pumped abstraction from water bores drilled into the aquifers.

For the GAB, like many other semi-arid to arid zone aquifers around the world, the current rate of recharge is significantly less than discharge. Groundwater currently stored in the Cadna-owie – Hooray Aquifer and equivalents is a legacy from higher recharge rates that occurred during much wetter periods in the early Holocene and Pleistocene age (essentially the last 2.6 million years).

The significance of the recharge zones to the GAB is not so much as an immediate water supply to central parts of the basin and natural discharge areas, but that they provide the pressure head (or weight of water) required to drive the water to the surface. Removal of this pressure through water abstraction associated particularly with Coal Seam Gas (where local drawdown of in excess of 1000 m can be experienced around gas fields) risks removing the driving force of many of the free flowing artesian bores and springs in the GAB.

1.2 Brief for this report

The brief provided to SoilFutures Consulting for this report was to undertake the following work;

1. Map known recharge areas of the Great Artesian Basin (GAB) using published and as 'up-to-date" as possible information; and

2. to comment on the extent of Gas and petroleum activities within the GAB, particularly with respect to positioning on recharge areas.

2. Materials and Methods

2.1 Great Artesian Basin Spatial Data Collection

Spatial data for the Great artesian Basin was obtained from the following sources.

Up to date boundary information, historical recharge zone information, and modern raster grid modelling recharge was sourced from Ransley and Smerdon (2012) and downloaded from www.ga.gov.au (Catalogue numbers 75904, 75842 and76932 respectively).

State data for gas and petroleum exploration licenses and production licenses were obtained from the following sources which are acknowledged as per the download license agreement for each state below:

1. NSW Trade & Investment, Resources & Energy (2014). Petroleum Titles (almost exclusively natural gas and coal seam gas) including production leases and Exploration leases and Applications. Downloaded from http://minview.minerals.nsw.gov.au/mv2web/mv2

2. Northern Territory Government (2014). Petroleum Applications (Including natural gas and petroleum) and Granted Exploration licences. Downloaded from http://geoscience.nt.gov.au/GeosambaU/strike_gs_webclient/default.aspx

3. Queensland Department of Natural Resources and Mines (2014). Exploration license leases, production license leases (Predominantly coal seam gas and natural gas). Downloaded from http://dds.information.qld.gov.au/dds

4. South Australian Department for Manufacturing, Innovation, Trade Resources and Energy (2014). Exploration license leases, production license leases for both natural gas and petroleum (oil). http://sarig.pir.sa.gav.au/Map

2.2 Manipulation of spatial data

The GAB wide datasets for recharge and boundary information where compiled in ArcView 3.3 (A Geographic Information System) as a base layer for an analysis of other mapped data. As the new recharge information was presented essentially as an image, it was categorised into recharge increments and then transformed into a shape file, so that area statistics of different recharge areas could be calculated.

Gas and petroleum lease data for each state was transformed to a common datum (WGS84) and a common projection (Albers Equal Area Conic). The data for each state was then merged into a single shapefile for ease of use.

2.3 Review of Recent Publications

This review is only a brief summary of select, up to date publications relating to recharge and discharge mechanisms and mapping in the GAB. The review helps to establish a model for how to process spatial data later in the report. It is important to note that the recharge calculations undertaken in this report do not include the Carpentaria Basin within the GAB, as this area has its own high recharge areas from overlying regional aquifers which do not affect the rest of the basin.

Ransley and Smerdon (2012) provide a thorough overview of recent research and conceptualization of the GAB. Figure 2 summarises recharge zones and their significance to the GAB. The eastern NSW section of the basin (The Surat Basin) and the Surat Basin extending into Queensland has some horizontal connectivity with the adjacent Eromanga Basin (the largest sub basin of the GAB) to the west.

The Surat Basin has about 10% connection with underlying aquifers. In addition to this, the Surat Basin has minor known discharge into the Gunnedah and Cubaroo formations which form the Namoi River Paleochannel at the northern end of the Pilliga outwash which bounds the Namoi Alluvium. These waters are still relatively fresh and augment irrigation aquifers and possibly surface flows in the Namoi between Narabri and Walgett.

Concern regarding CSG extraction is raised in Ransley and Smerdon (2012) in the following quote. "*CSG production in the Surat Basin targets the Jurassic Walloon Coal Measures. The main CSG producing fields are located in the northern Surat Basin in a broad arc extending from Dalby to Roma. For gas to be harvested, the coal seams need to be depressurised by pumping groundwater from tens of thousands of wells intersecting the Walloon Coal Measures. Drawdowns of several hundred metres will be generated by the depressurisation and significant volumes of groundwater are to be pumped from the Walloon Coal Measures – averaging about 75 to 98 GL/year over the next 60 years (RPS Australia East Pty Ltd, 2011). This process will induce drawdown in overlying and underlying GAB aquifers, the amount of which will depend on the leakiness of the system."*

Ransley and Smerdon (2012) summarise recharge in the following*: "Wohling et al (2013b) recently mapped recharge. Across the majority of the Surat Basin, recharge is estimated to be less than 5 mm/year, with the exception of portions of the Hutton Sandstone, which have values greater than 20 mm/year in the north part of the region. Similarly, recharge values of up to 45 mm/year were estimated for a localised region on the east side of the Coonamble Embayment. For the remainder of the eastern margin of the GAB, the spatial distribution and values are similar to those reported previously by Kellett et al (2003), less than 5 mm/year, with a trend for increasing recharge in the north of the region, with values up to 45 mm/year. Across the western margin of the GAB, recharge was effectively zero (mean of 0.15 mm/year)."*

Smerdon, Ransley, Radke and Kellett (2012) updated the geological knowledge base for the GAB and also revised the boundary of the GAB. This revised boundary is used in all of the below analyses of recharge and gas and petroleum related activities. They provide detailed information about the geological formations which contribute to recharge of the greater basin.

Recharge mechanisms are discussed in Herczeg and Love (2007) and fall into the following categories:

1. Via direct infiltration to the soil into the outcropping regions of the Jurassic Aquifers
2. Direct recharge through ephemeral creeks and rivers and mountain block alluvial fan systems (very important within the East Pilliga section of the Coonamble Embayment of the Surat Basin)
3. Downward hydraulic movement through aquifers above the GAB aquifers, where conditions permit

4. Upward hydraulic movement from aquifers underlying the GAB aquifers. This is thought to be happening in the Winton Sandstones in the central part of the wider GAB.

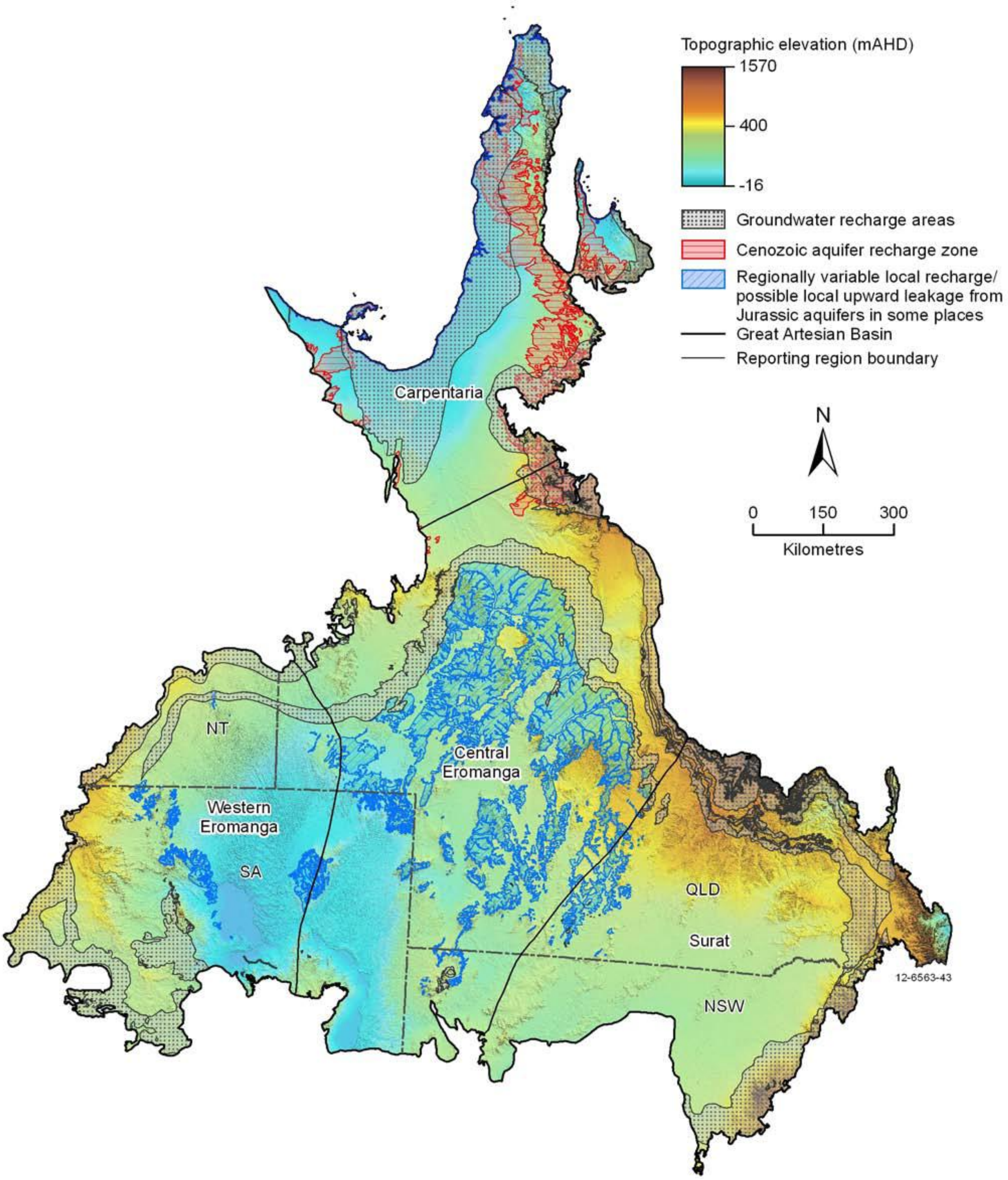

Figure 2: © CSIRO 2012 Hydrostratigraphy, hydrogeology and system conceptualisation of the Great Artesian Basin ▪ 17 Figure 2.2 Digital elevation model with Great Artesian Basin boundary and aquifer recharge zones.

3. Results of Analysis of Spatial Data

This section of the report provides a stepwise analysis of high quality modern spatial data relevant to recharge in the GAB. It shows the process by which areas were modeled and spatial statistics generated.

3.1 Recharge areas

Known mapped recharge areas for the GAB are separated into the Carpentaria basin recharge (not considered in this report), broad recharge associated with the Winton Block (in central QLD) which is thought to be recharged from underlying geology rather than from the surface), and the eastern and western margins of the GAB, which are generally considered to be the main recharge areas.

Figure 3 includes the Winton block recharge area (the central red area of the map), where water is thought to enter the GAB from pressurized aquifers underlying the main GAB aquifer. Surface recharge here is reported as poor (<0.1 mm/yr) No further consideration of these areas is given in this report.

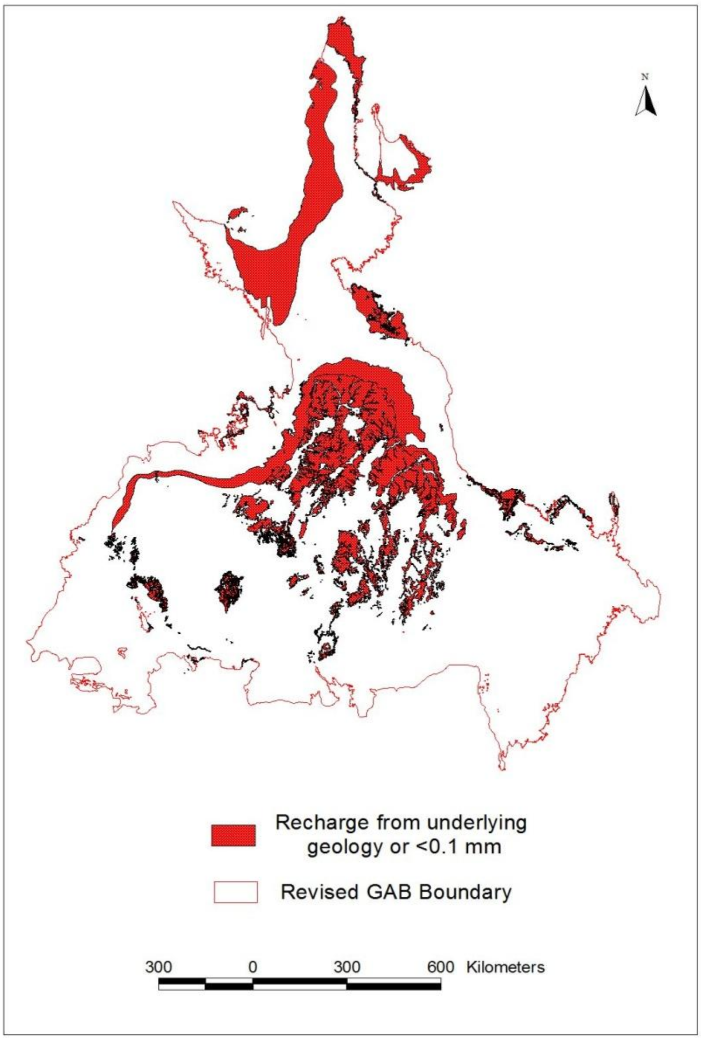

Figure 3: Poor recharge from surface yet likely recharge from underlying aquifers.

Figure 4 Shows known areas of recharge around the margins of the GAB, where recharge is through soil into underlying Cretaceous and Jurassic geologies or through alluvial fan systems which are prominent in the south eastern portion of the basin in the Pilliga Outwash. This figure shows that the total area of GAB marginal recharge (excluding Carpentaria) is 157 902 km^2 or 9% of the GAB.

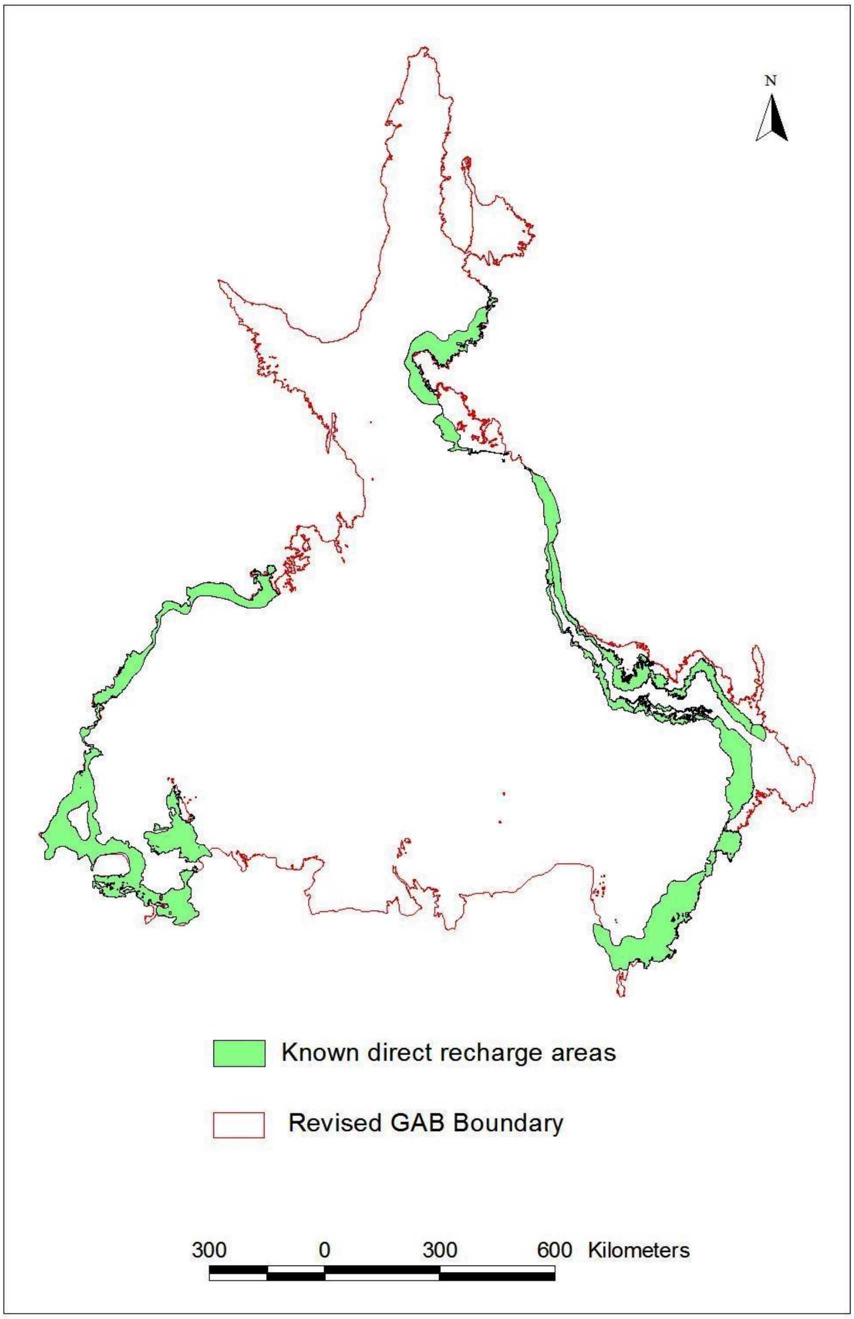

Figure 4: Direct recharge areas – margins of basin on Jurassic and Cretaceous Sandstones

Figure 5 shows the results of recharge measurement and modeling presented in Ransley and Smerdon (2012) and derived from Wohling *et al* (2012), Kellet and Ransley *et al* (2003) and Habermehl *et al* (2009) and are the most up to date assessment of GAB margin recharge available.

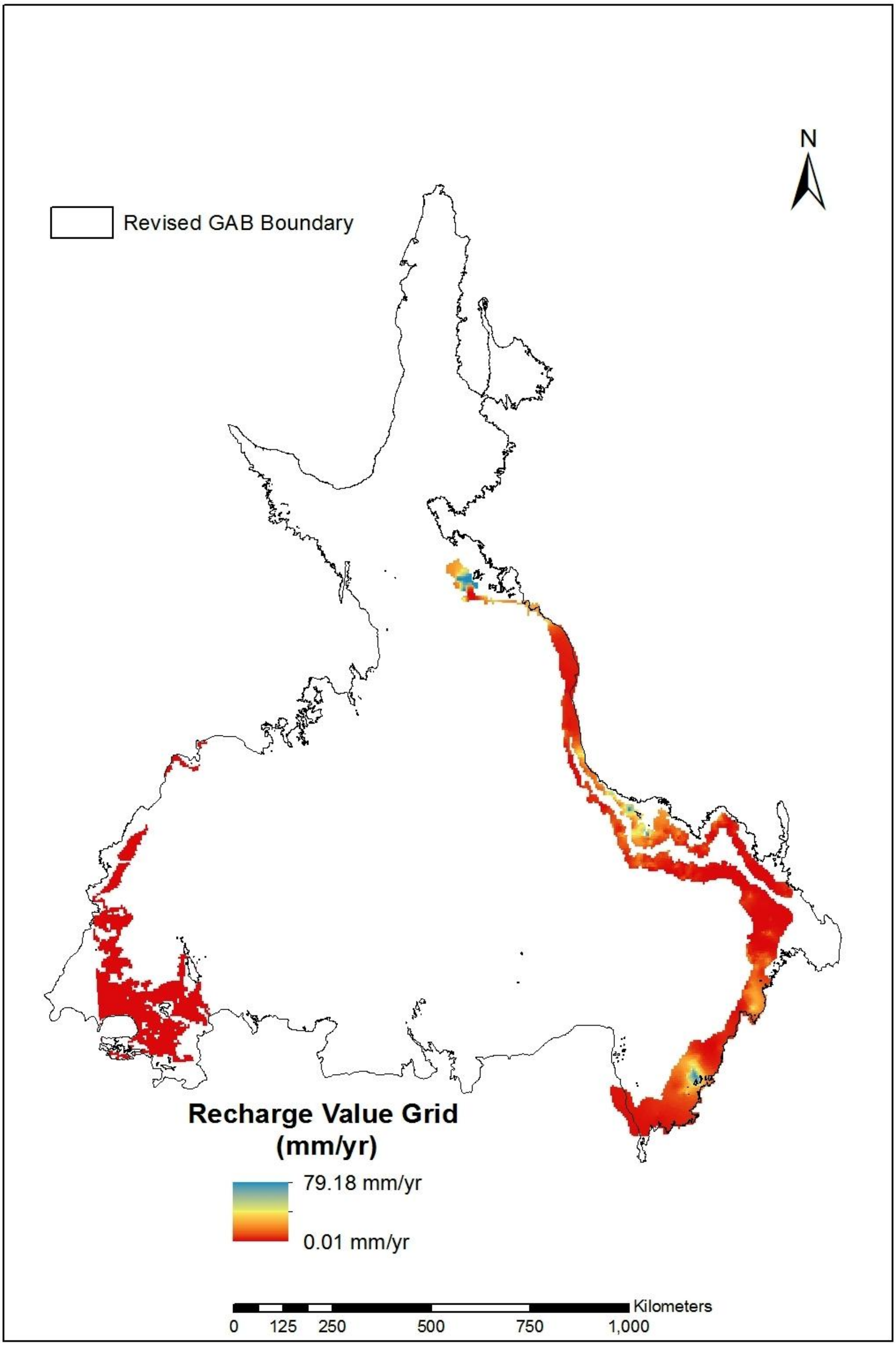

Figure 5: Modern recharge values for the GAB margins (from Ransley and Smerdon (2012)

The recharge categories presented in Figure 5 were machine digitized into the three zones which are presented in Figure 6 below.

Figure 6 shows the following. The area with 1 – 5 mm/yr recharge is 65 064 km^2, or 3.8% of the GAB. The area with 5 – 30 mm/yr recharge is 37 775 km^2 (2.1% of the GAB). The area with recharge greater than 30 mm/yr recharge is 2 847 km^2 (0.2% of the GAB). In NSW the recharge areas of higher than 5 mm/yr and >30 mm are almost entirely contained within the east Pilliga area. The total area with recharge > 1 mm/yr is 102 826 km^2, or 6% of the GAB.

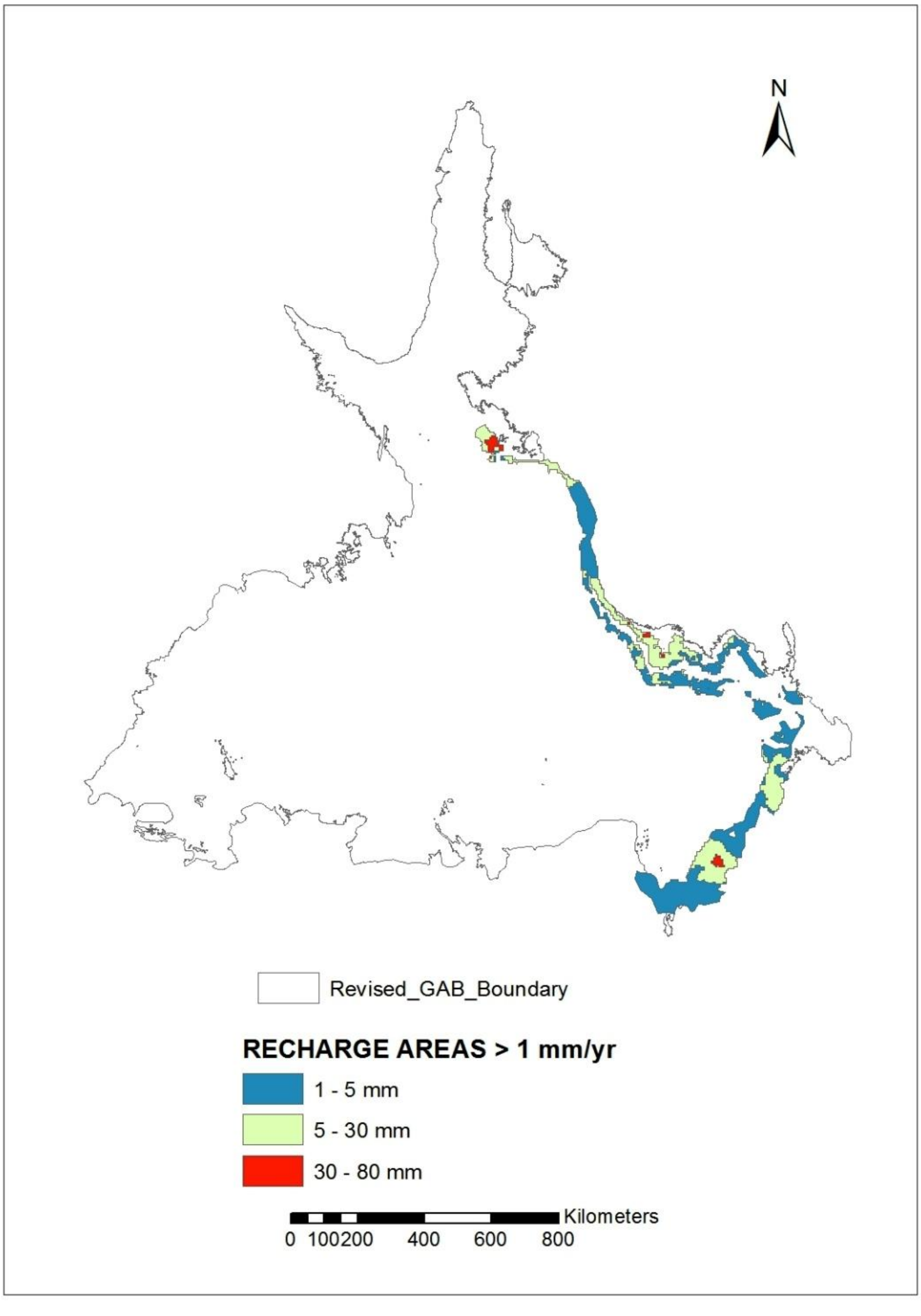

Figure 6: Machine digitised recharge zones from grid data provided in Figure 5.

3.2 Gas and petroleum data

Owing to the complex nature of the gas and petroleum data from the four differing states, it was decided to present both exploration license areas and production license areas on the same map. The data in Figure 7, show that 1.38 million km^2 (or 80% of the GAB) is taken up with exploration or production licenses associated with gas or petroleum.

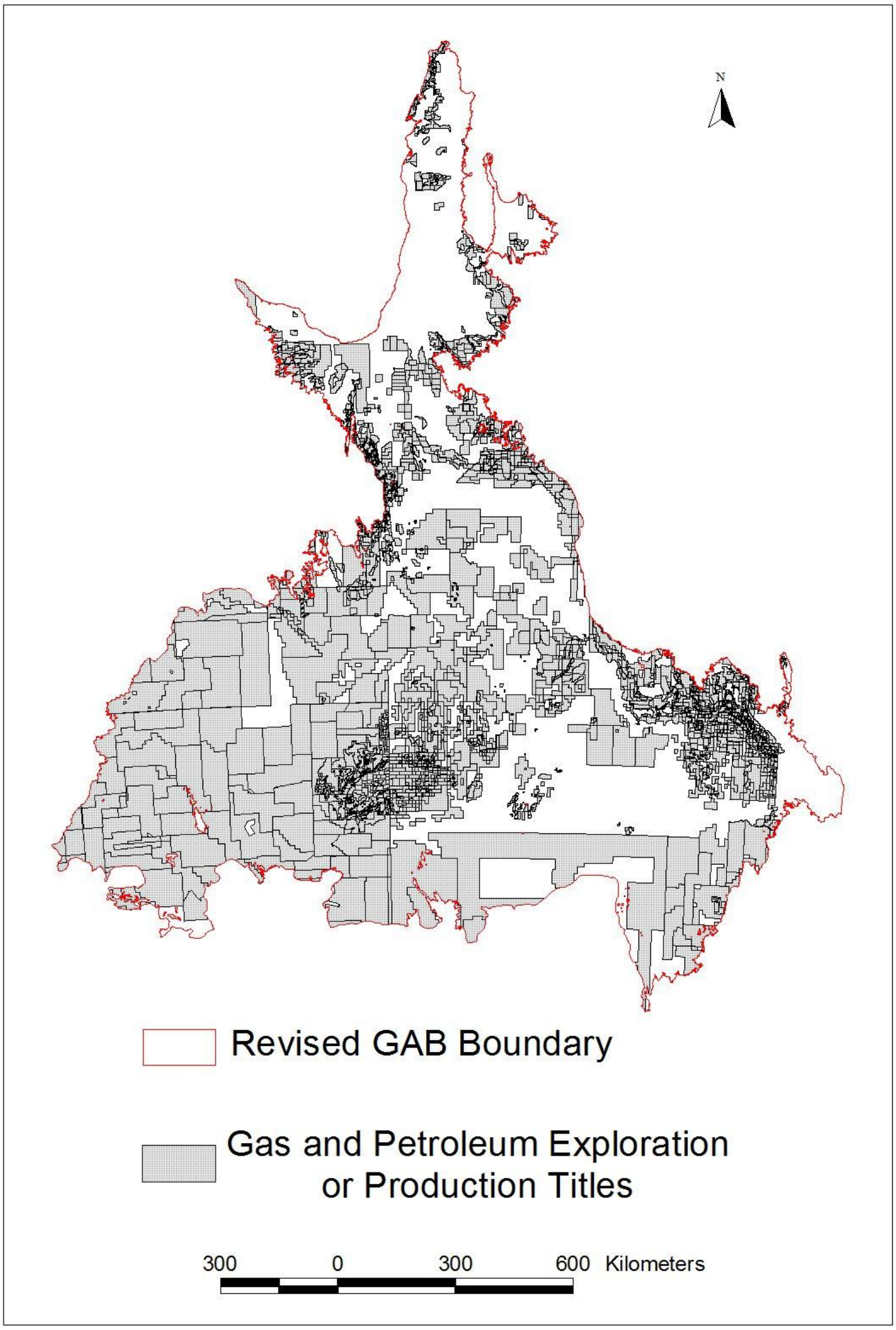

Figure 7: Extent of Gas or petroleum production and exploration licenses in the GAB

3.3 Gas/Petroleum license areas and Recharge

The data from Figure 7 were overlain with the digitised (polygon) version of the Cretaceous and Jurassic recharge zones on the magins of the GAB (Figure 6). Figure 8 shows the extent of gas and petroleum related license areas within the critical recharge zones (>1 mm/yr).

32 326 km^2 (or 31%) of the crtical recharge zone is not covered by any license. 70 590 km^2 (or 69%) of the critical recharge zone is taken up with either production or exploration leases.

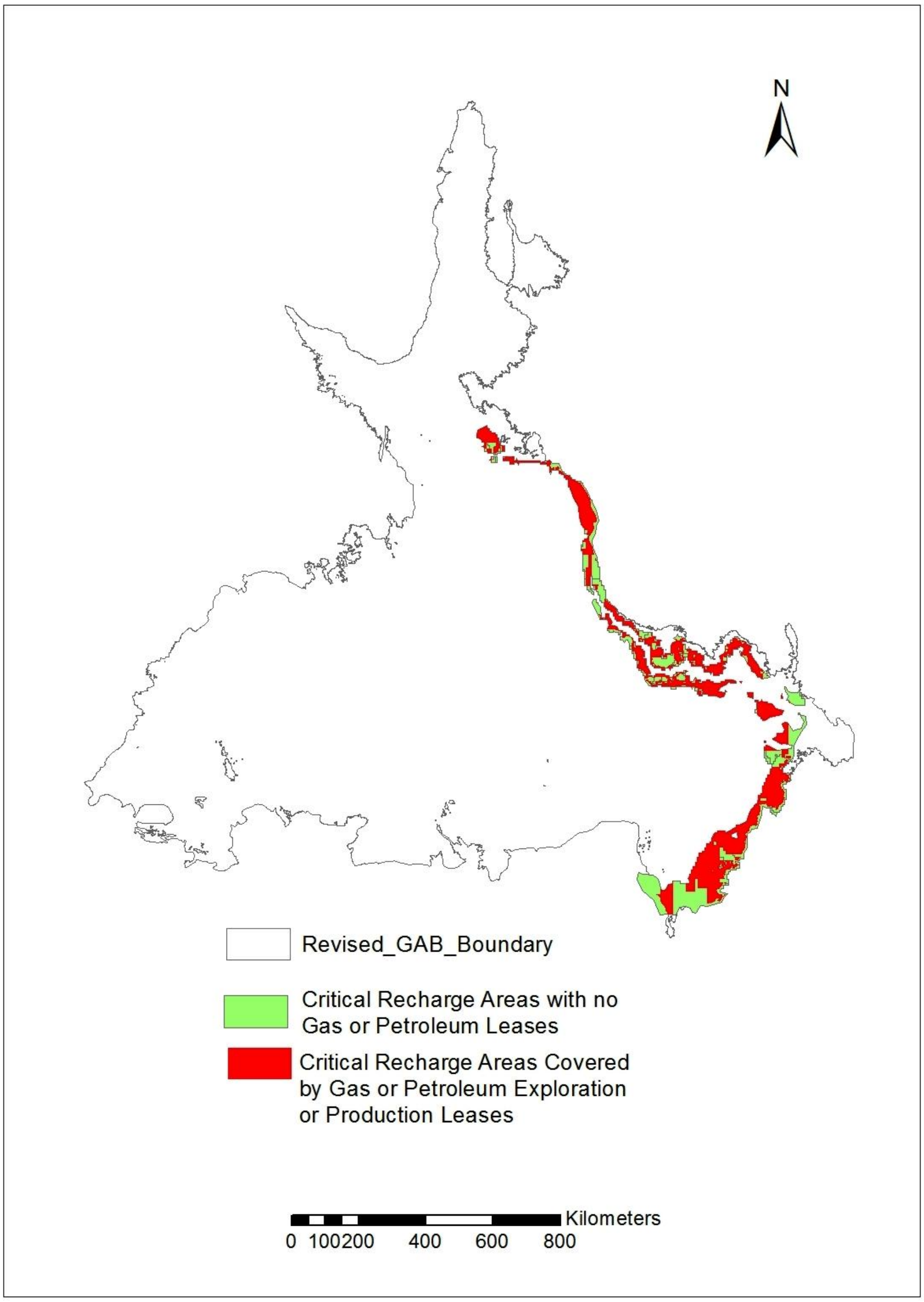

Figure 8: Extent of Gas/Petroleum production and exploration licenses within critical recharge zone (>1 mm/yr) of GAB

4. Discussion of results

The above results show that:

- Recharge along the Eastern Jurassic to Cretaceous margins of the GAB is crucial to providing hydraulic head which drives the whole system.
- Significant recharge to the bulk of the GAB is much more limited in area than previously thought with only 6% of its area providing more than 1 mm /yr.
- Although approximately 30% of the GAB is mapped as recharge, only 6% of the GAB is effective recharge which maintains the pressure head on the bulk of the GAB (excluding the Carpentaria basin).
- Only 2.3% of the GAB has effective recharge of greater than 5 mm/yr.
- Only 0.2% of the GAB has effective recharge of 30 – 79 mm/yr.
- In NSW, the main occurrence of recharge >30 mm is in the east Pilliga between Coonabarabran and Narrabri.
- Draw down of many hundreds of metres is reported in Ransley and Smerdon (2012) for the northern Surat basin coal seam gas fields where coal seams are being dewatered to release gas.
- Draw down of in excess of 1000 m is proposed in the Pilliga in the south eastern Surat Basin (ICSG Forum, 2014).
- Both of the Pilliga and the northern Surat gas fields or license areas occur in the very limited critical recharge (>30 mm) areas of the GAB.
- Excessive draw down of pressure heads in the recharge zone of the GAB associated with gas extraction, has the potential to reduced pressure heads on artesian waters across much of the GAB, and potentially stopping the free flow of waters to the surface at springs and bores.
- Gas and petroleum exploration and production licenses cover 80% of the entire GAB.
- Gas and petroleum exploration and production licenses cover 69% of the critical highest and most critical recharge areas of the GAB.

5. Concluding Remarks and Recommendations

This report clearly demonstrates that a very large percentage of the critical recharge areas of the GAB are covered with gas or petroleum exploration or production licenses. Although individual impact studies may have been carried out or may be carried out for each license on the impact of gas or petroleum extraction from beneath the GAB sediments, it is unlikely that an impact on the whole of the GAB can be assessed in this way.

The GAB covers large areas of Australia's two largest surface catchments, the Murray Darling Basin, and the Lake Ayre Basin and comprises a substantial portion of Australia's agricultural production.

Clearly the area of highest recharge (>5 mm/yr) within NSW is in the Pilliga Sandstones and associated colluvial fans of the East Pilliga. This area is almost completely covered with exploration licenses at this time. Most of the highest recharge areas within QLD are also substantially covered by gas or petroleum licenses for exploration and production.

The GAB is administered from four states which place differing values on its mineral and natural resources. Given that the four states within the GAB have different criteria by which to judge the suitability of a proposal for development, it seems that there is as yet no standard approach to gas and petroleum extraction approvals which cover the whole of the GAB. The current approval or issuing of licenses for both exploration and production in the GAB appears without coordination or regard to recharge. CSG extraction may significantly affect groundwater resources and groundwater resource access within the GAB if bores or springs begin to fail as a result of depressurisation caused by dewatering of recharge zones.

Consideration should be given to a basin wide approach to the management of the GAB with respect to minerals and natural resources, particularly with respect to potentially wide ranging activities such as gas and petroleum production where groundwater from below the GAB is drawn down and produced as an excess or waste byproduct of such development. In particular, serious thought needs to be given to the management of the few critical recharge zones within the GAB and how these might interact with future water supplies.

Recognition of CSG as a water user needs to be given parity with groundwater irrigation users. It needs to be monitored stringently to ensure that the overlying water resource (the GAB) is not affected and the recharge resource is properly managed to maintain hydraulic head.

The concept of the value of land in making development decisions with regard to CSG and mining in NSW has been developed significantly in the past few years. Biophysical Strategic Agricultural Lands (BSAL) were defined to place more rigorous consideration on extractive industry applications in areas of high agricultural productivity, or near special agricultural industry clusters (NSW Government 2013). BSAL areas address the agricultural potential of land only, and do not relate to other landscape functions. Landscape functions such as critical recharge zones to the GAB or other aquifer systems are not considered. A similar approach to delineating high value agricultural lands is Queensland is given in DERM (2012).

The East Pilliga area between Narrabri and Coonabarabran in NSW has Soil and Land Capability Classification (SLC) of between 4 and 6, meaning that there are no contiguous areas of Biophysical Agricultural Land (BSAL) in the area. BSAL is defined as Classes 1 to 3. This means that currently no special consideration which includes landscape function is given with regard to CSG and Mining applications in the critical recharge zone areas of the GAB within the East Pilliga.

A regulative approach which is applied in Germany on a regional scale to manage potential impacts on groundwater is the concept of "*Wasserschutzgebiet*", or clean water protection area. Despite having relatively high rainfall and low evaporation, Germany predominantly sources its drinking waters and waters for agricultural or industrial applications through groundwater. These legislated groundwater protection zones are in place to protect both water quality and quantity and all land uses are highly regulated with respect to groundwater and surface activities within sensitive zones. The sensitive zones include recharge areas and areas in proximity to water bores. This approach to recharge has now been modified and legislated for across the entire European Union (EU 2014).

This report establishes that the landscape function of critical recharge is an important consideration community and national land value that is generally not taken into account with regard to mining and CSG activities across the whole GAB. The landscape function of critical recharge to the GAB should be taken into account with regard to these activities. Prolonged deep draw down of aquifers under the GAB (associated with CSG) may eventually lead to a permanent loss of head to large areas of the GAB and as such this needs to be considered a very high risk activity extending far beyond the bounds of an individual gas field or mining activity.

Clearly an approach such as the German/European one, which controls all land use with regard to important recharge zones and other areas within the GAB, may be useful in avoiding potential catastrophic pressure losses. A nationwide management stratagem which includes critical recharge protection and regulates these industries within the GAB may prevent potential degradation of this essential groundwater resource which provides water to 22% of Australia.

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Appendix 1: Review of Revised Edition by NSW Minister for Water

Below is a copy of the review presented in person to the Artesian Bore Water Users Association by the NSW Minister for Water on 14th February at Coonamble.

NSW GOVERNMENT | Department of Primary Industries Office of Water

Review of *Great Artesian Basin Recharge Systems and Extent of Petroleum and Gas Leases*, SoilFutures Consulting Pty Ltd, October 2014, prepared for Artesian Bore Water Users Association

Report Scope

The report was prepared in response to a request from the Artesian Bore Water User Association (pg 4).

The report brief was to

1. "Map known recharge areas of the Great Artesian Basin (GAB) using published and as 'up-to-date' as possible information; and
2. To comment on the extent of Gas and petroleum activities within the GAB, particularly with respect to positioning on recharge areas." (pg5)

Review of Report

Sections 2 and 3 of the report explain the data sources and GIS process to compile the data for the report.

The data used is all publicly available. No new data or information is presented in the report.

Recharge figures have been taken from reports published under the GAB Water Resource Assessment (WRA) project undertaken by CSIRO and Geoscience Australia and is a reliable, and the most recent, data source. The reports published under the GAB WRA project went through a number of review processes.

Information on gas and petroleum leases has been obtained from the relevant state agency websites and is appropriate to the best of the Office of Water's knowledge.

Section 2.3 Review of Recent Publications

Pg 7 Suggestion that the discharge from the Surat Basin into the Lower Namoi alluvium contributes to surface flows in the Namoi River between Narrabri and Walgett is not substantiated and contradicts extensive groundwater monitoring data that this is a losing / losing disconnected reach. Research work undertaken under the Losing Streams Project by CSIRO in conjunction with NOW has demonstrated that the Namoi River in this area is a losing stream.

Pg 7 Reference to "concern regarding CSG extraction" in Ransley and Smerdon 2012 misrepresents the report. The quote presented is accurate but the report (Ransley and Smerdon 2012) does not express concern.

Section 4 Discussion of results

A number of issues are reported to be shown from the spatial representation of the published recharge data over gas and petroleum leases in the previous sections of the report. (NB the issues have been summarised for ease of this review, refer to SoilFutures report for full description of issue).

1. Recharge along the Jurassic to Cretaceous margins of the GAB is crucial to providing hydraulic head which drives the whole system.

   The report does not discuss the hydrodynamics of the GAB to substantiate this statement. It adopts a simple conceptualisation of the groundwater flows without recognising the large temporal and spatial influences on the GAB hydrodynamics.

1

There is a significant lag in the transfer of pressure changes in the GAB due to the size of the groundwater system. The magnitude of the pressure impacts also diminish with distance from the applied stress.

As explained in Ransley and Smerdon 2012, groundwater stored in the GAB is a legacy from higher recharge rates that occurred during much wetter periods in the early Holocene and Pleistocene age.

2. Recharge is more limited than previously thought.

   Given the recharge figures are based entirely on published data this statement is not supported by the published hydrogeology of the GAB.

3. Points 3 to 5 refer to percentage of "effective recharge which maintains the pressure head on the bulk of the GAB".

   A simple model is presented and significant contributions to the hydrodynamics are ignored. Given the area of particular interest to this report are the NSW recharge areas it is of little consequence that contributions in central and northern Queensland are not considered. Expressing this selected recharge as a percentage of the whole of the GAB without including other contributions to the groundwater flow systems distorts the significance of the data. However, the general point that the relative area of the GAB that receives diffuse rainfall recharge is small when compared to the entire GAB is valid.

4. Reference to many hundreds of metres of drawdown in the Surat Basin in Queensland (ie the Walloon Coal Measures) is correctly quoted. Note the Walloon Coal Measures are not present in the Coonamble Embayment of the Surat Basin in NSW.

5. "Draw down in excess of 1000m is proposed in the Pilliga in the south eastern Surat Basin (ICSG Forum, 2014)".

   This reference is not available, and this statement could be misleading by suggesting that this level of drawdown is predicted in the GAB in the Pilliga region.

   Information provided by Santos in support of development applications for pilot production in the Narrabri Gas Project does confirm that pressure drawdown in the order of 1,000m is predicted expected in the Maules Creek Formation of the Gunnedah Basin at CSG production bore sites. The report does not clarify that the predicted drawdowns relate to the target CSG production zone of the underlying Gunnedah Basin and not the Pilliga Sandstone of the south eastern Surat Basin. Reference to Pilliga in this point is geographic and not associated with the Pilliga Sandstone of the GAB.

6. Reference to "Excessive drawdown of pressure heads in the recharge zone.....potentially stopping the free flow of waters to the surface at springs and bores".

   This broad statement is not constrained geographically (eg Qld gas fields or NSW recharge area) nor does it clarify the depth to which the inferred pressure heads relate (Surat or Gunnedah Basin) to enable the context of the implied impacts to be assessed. It again assumes a simple model of the GAB and does not recognise the long response times of regional impacts.

Section 5. Concluding Remarks and Recommendations

This section appears to state opinion and apart from repeating previously noted interpretations does not purport to be presenting information of the GAB.

In the discussion of what should be considered in the management of the GAB the author has not referred to the specific management of the GAB recharge areas within NSW, including:

- all take of groundwater from the GAB has to be accounted for against the extraction limit set by the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008*, and
- the NSW Aquifer Interference Policy sets a minimum impact consideration of 15m of drawdown within the Southern Recharge Groundwater Source and that any flowing bore should not cease to flow.

The reference to the concept of "Wasserschutzgebiet" in Germany appears to misunderstand the typical use of this as a management tool. It is used to declare recharge protection areas around municipal bore fields to prevent contamination from activities in the vicinity of the well heads. It is typically done at the scale of tens to hundreds of metres.

Summary

The conclusions of the report appear to be based on general perceptions rather than a detailed understanding of the hydrogeology of the GAB. It also does not discuss the current NSW planning and policy frameworks under which the GAB and potential impacts to it are managed. A discussion on the current management of groundwater impacts would have been beneficial to the Artesian Bore Water Users Association providing them with a sound basis on which to discuss their concerns on potential impacts of CSG developments on the GAB.

The Office of Water suggests that addressing the matters raised in this review will improve the accuracy and usefulness of the report for the Artesian Bore Water Users Association.

Appendix 2: Summary of Criticisms and Authors Response

Issue: Page 1. No New information is provided in this report
Response: Although all data presented in this report is public domain, no single agency in Australia has compiled the data in this form to show the extent of petroleum, coal and CSG related activities in the GAB. This is new information – a new map compiled using the best available data.
Issue: Page 1: Comment re Namoi being a gaining or losing stream Narrabri to Walgett, using the Losing Streams Project (Lamontagne et al 2011).
Response: Whilst this is an interesting comment, the study area for this report is a 3km degrading stretch of river starting 12 km from Narrabri. It does not negate or hold in doubt question data also presented in Ransley and Smerdon (2012) which shows that the Namoi alluvial aquifers closer to Pilliga are gaining waters from the GAB. *It also appears from the wording of this that the revised edition of this report (SoilFutures, December 2014) was not reviewed, despite being provided to the NSW Minister for Water on 5th December, 2014.* *Lamontagne et al (2011) references a very small and eroding section of the Namoi River where as Ransley and Smerdon (2012) refers to more regional upward pressures into the Namoi Alluvial aquifers near Cuttabri which is between Narrabri and Walgett. There is no conflict here and the findings of Lamontagne et al (2011) needs to be considered in the context of the entire stretch of river mentioned. Cleary the reference quoted in the Ministerial Review is older than the reference quoted in the document.*
Issue: "Reference to Concern"
Response: This is a moot point but as one of the reviewers of the report was the author of Ransley and Smerdon (2012) and he agreed that he was expressing concern. Perhaps this is a misunderstanding of scientific language or just semantic.
Issue: Bottom of Page 1. "This report does not discuss the hydrodynamics……"
Response: The brief for the report did not include this. The does not present a conceptualisation of groundwater flows. It presents maps and creates new maps. There is no argument here and the point is not relevant to the document.
Issue: Page 2. Recharge is more limited than previously thought
Response: Traditionally, the recharge for the GAB has been thought to be 30% of the basin, and that it was significant. The recently published information contained in this report shows clearly that effective recharge (>1 mm/yr) is only 6% of the GAB. 6% is lower than 30% so it is hard to understand what the reviewer is trying to say in this instance.

Issue: Page 2 point 3. "A simple model …."

Response: *This criticism is misleading.*
Central and Northern Queensland are referenced and mapped with mention of CSG activities and impacts.

The Report does not focus on NSW – it is a GAB wide study referring to some points of interest within NSW.

The final sentence of this criticism negates the previous remarks "the general point that the relative area of the GAB that receives diffuse rainfall recharge is small when compared with the entire GAB is valid" however; the report also refers to the mountain block and alluvial fan recharge which is most common in NSW.

Issue: Page 2 point 4. "Reference to many hundreds of metres of drawdown"…

Response: The criticism says that the statement is correct so why this is mentioned is unknown. The point that this document makes is that there are known connections between the underlying Permian gas rich rocks and the Jurassic/ Cretaceous GAB aquifer and the removal of waters from the Permian rocks may result in drawdown in the Gab aquifer.

Issue: Page 2, Point 5. Reference to CSG forum and comment that this statement could be misleading.

Response: This is clearly referenced and the 1000 m drawdown is clearly available at http://csgscienceforum.com/contributor-reports/

The intent of this whole section of the report is to show that

1. *A 10% connection between the GAB sediments and the Permian and the overlying GAB aquifers exists (established)*
2. *A drawdown of 1000 m in the Permian layers could well therefore result in a significant loss of water out of the GAB recharge bed area. (Potential)*
3. *If such a loss happened, and it was say 40 m (which is enough to potentially threaten artesian water pressures at Coonamble, then a recharge rate of 1 – 30 mm/year, will ensure that it takes 1300 – 40 000 years to recover, if only surface recharge is required to refill the space created. (Risk of loss)*

There is no misleading information given in the report and no intent to mislead.

Issue: Point 6, page 2. This broad statement is not constrained geographically…….

Response: The report is about the Great Artesian Basin. It is geographically constrained to the Great Artesian Basin. It is about risk, and it is not intended to provide a hydrogeological model. No such model is proposed. It is the job of the various state and federal agencies to monitor and model the GAB or the part which they have legislative authority over. There are no data or peer reviewed publications currently publically available from these agencies to *show that this has been done.*

Issue: "long response times of regional impacts" not recognised.

Response: The document is about risk. Response times are not mentioned because none of the federal or state bodies have published any response times. It is interesting to note that (in NSW) over 30% of artesian bores in the GAB are no longer artesian due to pressure losses. These local effects happened within a 140 year time frame or less.

Even though the minster or his staff has made the comment about response times, he has no furnished any data to suggest a length of time for such a risk scenario to impact on water supplies. Clearly if the impact is in tens to hundreds of years, there is a big problem. If it is to the order of millions of years, it is unlikely to be an issue for the human race.

Issue: Section 5. Page 3. This section states opinion …..

Response: The conclusions show that there is a risk of dewatering partially connected aquifers with regard to pressure gradients in the GAB.

Note that the title of this section of the report also says "Recommendations". The recommendations are based on knowledge presented in the report and the experience of the author.

It is the job of a scientist to express a considered and informed opinion.

Issue: Remarks regarding NSW State Policy and lack of inclusion in the report

Response:

1. *The report is not about NSW, it is about the GAB.*
2. *The policy of a particular agency is irrelevant to the identification or existence of risk*
3. *The agency who apparently provided the review has not published anything to do with the risk in the scientific literature so no comment on how risk is proposed to be managed is made.*

Issue: Comment on "Wasserschutzgebiet" is incorrect

Response: Obviously the reviewer has no recent knowledge on European Legislation with regard to groundwater management, not have they made contact with the relevant qualified persons in German Government (such as Dr Gredner, whose details are provided in the acknowledgements section of this document). Dr Gredner would be happy to furnish any information that the NSW Minister for Water Requires in this matter.

Conclusion of Response to Review

The review provided by the NSW Minister for Water, shows that the intent of; and the issues raised in this report have not been clearly understood by the reviewer. Although the minister was furnished with a revised edition of the report in early December 2014, the former version of the report was reviewed. The revised edition of the report was peer reviewed with reviewers acknowledged for their comment. Clearly the NSW Minister for Water chose not to have the Revised Edition reviewed.

The Revised Edition was also presented in person to Mr Troy Grant, NSW Deputy Premier in his offices at Dubbo on 19th December, 2014. The NSW Deputy Premier undertook to pass a copy of the Revised Edition to the Office of the NSW Chief Scientist.

Whilst the NSW Minister for Water has made comments such as those on response times, he or his staff has provided no suggestion as to response times. There are currently no peer reviewed and published data on this relevant to the entire GAB.

Some issues arising such as not using up to date data are incorrect. The suggestion that the Namoi River is a losing stream between Narrabri and Walgett is based on some science done on one 3 km stretch of river published in 2011. The discussion represented about the alluvial aquifers and possible surface recharge to streams was published in 2012. Clearly the regional information quoted is more recent and more regionally relevant that data for a 3 km stretch of the Namoi River.

The main issue raised in the report is that of risk to pressure heads which drive the GAB through extraction of waters in aquifers beneath the GAB which are partially connected to the GAB. There appears to be no dispute on behalf of the reviewer over this issue.

The conclusion of the report is that the highly localised critical recharge areas identified are the only places where the significant recharge waters can get into the GAB. Potential lowering the hydraulic head in these critical areas is therefore important. This is not held in dispute in the NSW Minster for Water's review.

It is the function and responsibility of the State and Federal Agencies that are responsible to manage the GAB to assess this risk and to publish findings on how it can be managed. Unfortunately, "policy" quoted by the reviewer; which may have the intent of risk management; does not explain what science has been done to ensure that the "policy" will be effective.

It was not the role of the author of this document to comment on policy, but available data and publications. A suggestion is given in the conclusions of this report, that a national approach to GAB pressure management which ignores State boundaries may be useful in managing highlighted risks. It does suggest the European model as a potential framework, but this is as far as any reference to policy occurs in the document.