Nitrate exposure from drinking water in Denmark over the last 35 years

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Abstract
In Denmark, drinking water quality data covering the entire country for over 35 years are registered in a publicly-accessible database. These data were analysed to determine the fraction of population exposed to elevated nitrate concentrations. Data from 2,852 water supply areas from the 98 Danish municipalities were collected in one dataset. Public water supplies are extensively registered; private wells supplying only few households are neither monitored nor registered sufficiently. The study showed that 5.1% of the Danish population was exposed to nitrate concentrations > 25 mg L$^{-1}$ in 2012. Private well users were far more prone to exposure to elevated nitrate concentrations than consumers connected to public supplies. While the fraction exposed to elevated nitrate concentrations amongst public supply users has been decreasing since the 1970s, it has been increasing amongst private well users, leading to the hypothesis that the decrease in nitrate concentrations in drinking water is mainly due to structural changes and not improvement of the groundwater quality. A combination of this new drinking water quality map with extensive Danish health registers would permit an epidemiological study on health effects of nitrate, as long as the lack of data on private well users is addressed.

Keywords: nitrogen, nitrate, monitoring, drinking water quality, trends, exposure

1. Introduction
Nitrate in drinking water has been suspected to negatively affect human health, amongst others as a cause of cancer. However, no clear evidence has been found yet (Jensen 1982, De Roos et al 2003, Ward et al 2005). An assessment of social costs of colon cancer due to nitrate in drinking water in 11 EU member states estimated that Denmark had the largest percentage of population (16.2%) exposed to elevated nitrate concentrations (> 25 mg L$^{-1}$ as NO$_3$) (van Grinsven et al 2010). The associated social costs due to loss of healthy life years were with 6.6 euro/capita more than double the average of the assessed 11 EU states. Van Grinsven et al (2010) based these estimates on models on nitrogen leaching, taking into account the fraction of population connected to large public supply systems or private wells, but not actual measured data on the nitrate content in Danish drinking water.

In assessments of the costs and benefits of economic policy instruments of nitrogen regulation in agriculture, most economic benefits are related to drinking water health-impacts, rather than to improvements in surface water quality as such (Andersen et al 2013). As the health effects of nitrate in drinking water appear to have a crucial impact on the overall assessment of nitrogen use in agriculture and to be extremely site-specific (Andersen et al 2011), an evaluation of the exposed population with high spatial resolution is justified. In Denmark, this is possible, as a nationwide database on drinking water quality (JUPITER3) is available, dating back many decades.
The goal of this study is to quantify the exposure to nitrate from drinking water for the whole Danish population during the last decades and to evaluate the quality of the available data in the JUPITER database for the purposes of a later epidemiological study. The drinking water nitrate data are interpreted by analysing the registered dataset. Furthermore, to our knowledge, for the first time all Danish public water supplies were assigned to the area they supply, making it possible to use GIS-analyses with the highest precision to date. Thus, it is now possible to analyse the exposure of water consumers to all monitored drinking water quality parameters for the entire country of 5.5 million inhabitants.

1.1. Water supply in Denmark

The Danish water supply is solely based on simple treated groundwater, and protection of groundwater has therefore a high priority. At the same time, Danish farming is among the most intensive in the world. Numerous waterworks and wells have been closed due to nitrate pollution (Environmental Agency 1998), and approximately 15% of the area of Denmark has been classified as nitrate vulnerable groundwater abstraction areas (Hansen and Thorling 2008). Since the 1980s, regulations implemented by Danish farmers have succeeded in optimizing the N (nitrogen) management at farm level, and the overall national upward trend of the nitrate concentrations in oxic groundwater was reversed around 1980. On a national level, the N-surplus has been reduced by approximately 40% from 1980 to 2007 and the nitrate concentrations in oxic groundwater have reduced by also approximately 40% from 1980 to 2000 (Hansen et al. 2011). Locally, nitrate trend analyses in monitoring wells have shown a more complex pattern with both upward and downward nitrate trends depending on the age of the groundwater and local agro-hydro-geochemical conditions (Hansen et al. 2012). Therefore site-specific groundwater monitoring and protection plans are being carried out in order to further protect drinking water resources from nitrate pollution.

The water supply structure is highly decentralized: approximately 2,600 public waterworks supply five million inhabitants, while the remaining approximately 0.4 million inhabitants use water from approximately 70,000 private wells (Nature Agency 2012). Public water supply is the main source of drinking water, bottled water consumption being amongst the lowest in the EU, with only one fifth of the EU average (UNESDA 2014).

1.2. Drinking water quality data

Danish drinking water quality is regulated and monitored routinely. Historically, the yearly frequency of the nitrate analyses at each waterworks has been variable. Currently, the nitrate content of drinking water is monitored routinely for waterworks with abstraction higher than 3,000 m³ per year. The frequency of the nitrate analyses varies from 1 every second year to 37 analyses per year depending on the abstraction volume (MoE 2014). For the smaller waterworks the frequency of the nitrate analyses depends on the policies of the local municipality. While some municipalities request analyses every fifth year, others leave it up to the owners to monitor their water quality. All nitrate analyses of the drinking water are performed by certified Danish laboratories and registered in the publicly available geo-database JUPITER.

2. Methods

2.1. Water quality dataset

The registered waterworks were divided into public supplies, supplying 10 or more households and private wells, supplying less than 10 households (WHO 2011). All registered nitrate concentrations were extracted from JUPITER in October 2013. Annual mean concentrations were calculated for each well field. Measurements below the detection limit were set to half its value (European Commission 2009). The detection limit varied from 0.001 mg L⁻¹ to 1 mg L⁻¹. For 10% of the public supplies and 61% of the private wells no coordinates were registered in JUPITER. For these, addresses were geo-coded using ESRI’s ArcGIS World Geocode Service, resulting in a total of 95% and 93% of public supplies and private wells, respectively, with both coordinates and nitrate measurements.

2.2. Exposure estimations

Four methods with increasing work effort were applied and compared to estimate the exposure to nitrate from drinking water over time. For all methods it was assumed that the ratio of publicly and privately supplied residents remained constant over time (5 : 0.4, see 1.1):

- **Step 1: By analyses (public supplies & private wells).** In a first step, annual mean concentrations for each waterworks with registered nitrate measurements for the given year were analyzed. This yielded the largest available dataset of the applied methods. Each waterworks was assumed to supply the same share of the population. It is assumed that the data for each year are representative of the whole population for publicly and privately supplied residents, respectively.

- **Step 2: By abstraction volume (public supplies).** In the above method, all waterworks are weighted equally. As a second step, concentrations were weighted by the annual abstraction volume of the respective waterworks. However, as registrations of abstraction volumes in JUPITER are incomplete, this leads to a smaller dataset. Only 3% of the private wells have abstraction volumes registered. Therefore, only the first step was applied on the private wells.

- **Step 3: By Thiessen polygons (public supplies).** Thiessen polygons were created for each year, based on the public supplies. The whole country was divided into water supply areas with assigned nitrate concentrations,
assuming every point in the country is supplied by its nearest public supply.

- **Step 4: By water supply areas (public supplies).** To achieve highest possible spatial precision of exposure, Denmark was divided into public water supply areas as shown in figure 1. Information on the areas that are supplied by each waterworks is not registered centrally in JUPITER, but locally in the 98 municipalities. Most municipalities have an administrative tool called water supply plan, which shows water supply areas with varying degree of precision. While some municipalities divide their whole area into public water supply areas, others show the actual supplied areas and leave unpopulated or non-supplied areas blank. It is important to notice that even though a resident lives in a water supply area, they might not be connected to the public supply, but get their drinking water from a privately owned well. Where a water supply plan was missing, municipalities or waterworks were contacted directly. Table 1 summarizes the sources. In total 2,852 water supply areas were assigned the water quality measurements of the public supplies by which they are supplied.

74% of the water supply areas are supplied by only one waterworks. 22% have more than one waterworks supplying the area and 4% are supplied by large waterworks that distribute their water into several areas (typically the large waterworks of the main cities).

For steps 3 and 4, a population density map was created using population counts in the 2,323 Danish parishes in 2008. Parishes are the smallest census units, leading to the highest spatial resolution. The population density was calculated and the polygon data converted into a raster map with a resolution of 500 m by 500 m. The total number of inhabitants in each Thiessen polygon and water supply area was calculated in GIS.

### 2.3. Trend analyses

The change in fraction of population exposed to low nitrate concentrations (< 10 mg L\(^{-1}\)) and elevated nitrate concentrations (> 25 mg L\(^{-1}\)) was analyzed using a standard linear regression model. 95%-confidence intervals of the trends were calculated and the null hypothesis (no trend over time) was tested on statistical significance (\(\alpha = 0.05\)). Trend analyses were computed for both public supplies and private wells for the period 1978–2012. For the public supplies, the results from step 4 were used; for the private wells, the results from step 1 were used. This was done for the whole of Denmark, as well as for the 10 so-called geo-regions (Kronvang et al 2008, Hansen et al 2012), see figure 1.

### 3. Results

Figure 2 shows the number of waterworks with registered nitrate measurements per year for public supplies and private wells, respectively. For the public supplies, the expected number of approximately 2,600 (Nature Agency 2012) is reached in the beginning of the 1980s. The registration of
nitrate measurements from private wells is on a very low level until the municipal reform in 2007, whereupon the registrations increase to approximately 8% of the total 70,000.

Figure 3 shows the water supply areas from step 4 with their assigned nitrate concentrations from the public supplies at different time steps. During the 1970s, only parts of Jylland and the island of Fyn (in geo-region VII) had registered nitrate measurements. During the 1980s, additional public supplies from eastern Jylland and eastern Sjælland were registered. By the 1990s, the whole country was covered.

3.1. Public water supplies

The following analysis is based on the results from step 4, where the exposed population to different nitrate concentrations is calculated by using the water supply areas and a population density map. Figure 4(a) shows the percentage of consumers using public water supplies exposed to different nitrate concentration classes, normalized to the total available data per year. The solid line depicts the percentage of the number of consumers that were assigned a nitrate exposure from public supplies that year in relation to the total population in the density map (5.4 million). The missing values to
100% correspond to the population in the ‘empty’ areas in figure 3. During the 1970s, less than 25% of the total population could be assigned a nitrate exposure from drinking water. The coverage increases in the 1980s to approximately 70%; and from 1991, more than 90% of the total population could be classified in a nitrate exposure class.

From figures 3 and 4(a), a general downward tendency in concentrations can be observed. Concentrations above the drinking water standard of 50 mg L$^{-1}$ are getting less frequent over time. While the standard was exceeded for up to 7% of the publicly supplied consumers in the 1970s, this is the case for only 3 in 10 000 in the latest complete dataset (2012). The percentage exposed to low nitrate concentrations (<10 mg L$^{-1}$) is increasing over time, from approximately 70% in 1980 to 94% from 2006.

Table 2 shows the percentage of consumers supplied by public supplies exposed to low (<10 mg L$^{-1}$) and elevated (>25 mg L$^{-1}$) nitrate concentrations in 2012, as well as the change since 1978. For all geo-regions, 2.5% of the population connected to public supplies was exposed to elevated nitrate concentrations in 2012. However, there is a large spread between the geo-regions. Noticeable is especially the northern part of Jylland: in Thy (III), Nordjylland (IV) and Himmerland (V) between 11% and 16% were exposed to elevated concentrations in 2012. However, there is a large spread between the geo-regions. Noticeable is especially the northern part of Jylland: in Thy (III), Nordjylland (IV) and Himmerland (V) between 11% and 16% were exposed to elevated concentrations. Contrarily, in the eastern part of Denmark (geo-regions VII-X) less than 0.5% of the population was exposed to elevated nitrate concentrations in public drinking water in 2012.

For the whole of Denmark, a statistically significant increase in the percentage of publicly supplied consumers exposed to low concentrations of 0.85 (0.75; 0.94) percent-points per year can be observed. For all geo-regions, except Bornholm (X), such a statistically significant increase is found. For the population exposed to elevated concentrations (>25 mg L$^{-1}$), the statistically significant national downward trend of 0.29 (0.23; 0.36) percent-points per year is reflected in all of the geo-regions, except Nordjylland (IV). Here, the population exposed to elevated concentrations has been statistically significant increasing and was in 2012 on the highest level of all geo-regions (16%).

Table 4 shows the estimated percentage of publicly supplied consumers exposed to elevated nitrate concentrations (>25 mg L$^{-1}$) for each method (step 1 to 4). The two first steps estimated this group with 4.8% and 3.7% slightly higher than the spatially referenced steps 3 and 4 with 3.1% and 2.5% in 2012. Weighing all analyses equally as in the first method, overestimates the population exposed to elevated nitrate concentrations, as the very large water supply companies in the main cities supply large water volumes with low nitrate concentrations to a large number of urban residents. An important exception is the city of Aalborg (pop. 110,000), located in geo-region Himmerland (V). Here, in the 1970s and 1980s annual averages above the drinking water standard of 50 mg L$^{-1}$ were common and reached up to 175 mg L$^{-1}$ for some water supply areas. In 2012, most of the water supply areas in the city of Aalborg are classified in the 25–50 mg L$^{-1}$ class.

### 3.2. Private wells

Figure 4 (b) shows the percentage of private wells in different nitrate concentration classes, normed to the total number of registered private wells per year. The solid line depicts the percentage of private wells with registered nitrate concentrations per year in relation to the total 70,000. As only the method in step 1 was carried out on the private well data, it is assumed that each private well is supplying the same number of residents. This implies that the percentage of private wells in a nitrate concentration class is equal to the percentage of exposed consumers in this class. As shown above, the data on private wells is much sparser compared to public supplies. However, looking at the distribution of population in the exposure classes, no obvious change can be observed during
Table 2. Public waterworks: percentage of consumers of publicly supplied drinking water exposed to low (< 10 mg L\(^{-1}\)) and elevated (> 25 mg L\(^{-1}\)) nitrate concentrations in Denmark and the 10 geo-regions in 2012. Annual changes from 1978 to 2012 in percent-points [pp/a] with 95%-confidence intervals in parentheses.

| Geo-region    | Below 10 mg L\(^{-1}\) 2012 (%) | Change (pp/a) | Above 25 mg L\(^{-1}\) 2012 (%) | Change (pp/a) |
|---------------|----------------------------------|---------------|----------------------------------|---------------|
| I Vestjylland | 97                               | 2.21 (1.69; 2.72) | 16                               | 0.33 (0.20; 0.48) |
| II Midtjylland| 97                               | 1.66 (1.43; 1.89) | 15                               | 1.20 (1.63; 0.78) |
| III Thy       | 99                               | 0.93 (0.62; 1.23) | 0.4                              | 0.11 (-0.15; 0.07) |
| IV Nordjylland| 72                               | 1.47 (1.24; 1.69) | 1.8                              | -0.59 (-0.74; -0.42) |
| V Himmerland  | 68                               | 1.04 (0.75; 1.34) | 0.3                              | -0.25 (-0.33; -0.17) |
| VI Djursland  | 64                               | 0.93 (0.39; 0.53) | 0.4                              | -1.20 (-1.63; 0.78) |
| VII Østdanmark| 99                               | 0.46 (0.39; 0.53) | 0.2                              | -0.11 (-0.15; 0.07) |
| VIII Nordsjælland\(^{a}\) | 98 | 1.13 (0.76; 1.49) | 0.3                              | -0.73 (-1.05; -0.41) |
| IX Sydsjælland | 96 | 0.45 (0.24; 0.66) | 0.4                              | -0.09 (-0.13; -0.06) |
| X Bornholm\(^{b}\) | 97 | 0.48 (-0.05; 1.00) | 0.0                              | -0.05 (-0.10; -0.01) |
| DK Denmark    | 91                               | 0.85 (0.75; 0.94) | 2.5                              | -0.29 (-0.36; -0.23) |

\(^{a}\) Time series from 1980.

\(^{b}\) Time series from 1991.

\(^{c}\) Trend not statistically significant (p = 0.08).

The increase from 2% in 2006 to 7% in 2008. Therefore, the private wells registered before 2007, even though accounting for only approximately 1% of the total number of private wells, are assumed to be representative of the private wells registered after 2007. However, it has to be kept in mind, that only a small fraction of the estimated total 70 000 private wells is registered. Whether there is registration bias (i.e. owners of poorly installed wells avoid registration), cannot be answered here.

A clear difference to the development of public water supplies can be seen in figure 4(b): the percentage of private well users exposed to nitrate in drinking water above the standard of 50 mg L\(^{-1}\) is substantial, between 14% and 30% over the last 30 years. As shown in table 3, the nationwide trend is opposite to the one of the public supplies: the group exposed to low concentrations is statistically significant decreasing by 0.22 (0.10; 0.35) percent-points per year, while the group exposed to elevated concentrations is statistically significant increasing by 0.13 (0.00; 0.25) percent-points per year.

In 2012, 37% of all private well users were exposed to elevated nitrate concentrations (> 25 mg L\(^{-1}\)) in drinking water. Nordsjælland (VIII) was the only geo-region with less than 25%. As in public supplies, the geo-regions on Jylland have the highest levels.

At the geo-region-level, the trends show no overall pattern and are mostly not statistically significant. Significant trends can be observed in the group exposed to low concentrations, which decreased in Vestjylland (I), Østdanmark (VII) and Sydsjælland (IX), while there was an increase in

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Djursland (VI). The group exposed to elevated concentrations decreased in Djursland (VI) and increased in Sydsjælland (IX).

4. Discussion

Water treatment works in Denmark do not usually have nitrate removal, so the concentrations of nitrate in drinking water can be expected to be similar to the concentrations in groundwater. The concentration level of nitrate in groundwater and drinking water is mainly dependent on (Hansen et al. 2011, 2012): (i) the age of the groundwater, (ii) the screen depth of the groundwater abstraction, (iii) the local depth of the nitrate interface (division between shallower nitrate containing groundwater and deeper nitrate-free reduced groundwater), (iv) the leaching of nitrate from agricultural activities and (v) the local hydro-geological conditions.

All the public water supplies except in Nordjylland (IV) have been able to reduce the percentage of consumers receiving nitrate in drinking water at elevated concentrations and nationwide only a minor part (2.5%) of the consumers received more than 25 mg L$^{-1}$ in 2012. The highest concentrations of nitrate in drinking water are observed in the northern part of Jylland (Thy (III), Nordjylland (IV) and Himmerland (V)) where 11–16% of the consumers of public water received more than 25 mg L$^{-1}$ in 2012. A comparable situation exists for the private wells. These findings can be explained by a high N-surplus in agriculture and high concentrations of nitrate in groundwater in these geo-regions (Hansen et al. 2012), in connection with difficulties in finding nitrate-free groundwater of good quality due to local hydro-geological and geochemical settings.

The private wells in all the geo-regions in Jylland have a high percentage (25–54%) of consumers receiving more than 25 mg L$^{-1}$ nitrate in their drinking water. This is a result of nitrate leaching from agriculture, possible technical problems with the wells and probably also lacking awareness of addressing and solving the problem.

Both at a national and a geo-regional level, the trend in nitrate concentrations in drinking water during the last 35 years is affected by both trends in groundwater nitrate concentrations (Hansen et al. 2011, 2012) and structural changes in the public supplies, both by technical and planning measures. Groundwater nitrate trends are influenced by change in groundwater recharge and changes in leaching of nitrate (N surplus) from agricultural activities. Structural changes include (i) relocating well fields to areas where it is possible to abstract nitrate-free reduced groundwater from deeper aquifers, (ii) mixing of waters and (iii) merging of water supply companies. In contrast to private wells, public supplies are regularly monitored and have the obligation and resources to take measures against non-compliance with the drinking water standards. While public supplies succeeded in reducing the number of exposed consumers to elevated nitrate concentrations, the opposite was the case for users of private wells. This could be due to the fact that structural changes are the main reason for the decreasing nitrate concentrations in public water supplies (compare to Thorling et al. 2012), as private well owners cannot relocate easily to other groundwater sources and might not have the resources to carry out such measures. However, interpretation of the drinking water nitrate trends observed at both the public water supplies and the private wells in relation to agricultural N losses is not directly possible due to lacking information on the age of the abstracted groundwater. Therefore it is not possible to directly deduce whether the causes of the observed trends of nitrate in drinking water are due to changes in groundwater nitrate concentrations or changes in structural development at the waterworks.

All four methods yielded an overall population exposed to elevated nitrate concentrations (> 25 mg L$^{-1}$) in drinking water in Denmark considerably below the estimated 16.2% in the European assessment (van Grinsven et al. 2010). However, as can be seen in table 4, the finding that an important variable is ‘the percentage of the population connected to public supply’ (van Grinsven et al. 2010) is confirmed for Danish settings. While the results of the estimated total population exposed to elevated nitrate concentrations vary between the different methods for step 1 to 4 in the beginning of the analysis period, they converge as the data coverage gets larger during the period. In 2012, it is estimated that 5.1%–7.2% of the total Danish population are exposed to elevated nitrate concentrations above 25 mg L$^{-1}$ in drinking water. The lower value of 5.1% has the most extensive exposure estimation method as a background and is therefore considered most reliable.

In absolute numbers, 128 200 Danish consumers of public drinking water were exposed to nitrate concentrations > 25 mg L$^{-1}$ in 2012. Of these, for 1 700 the drinking water standard of 50 mg L$^{-1}$ was exceeded. Even though accounting for only approximately 7% of the total population, 149 600 consumers of water from private wells were exposed to nitrate concentrations > 25 mg L$^{-1}$ in 2012. Of these, for the substantial number of 68 000 consumers the drinking water standard of 50 mg L$^{-1}$ was exceeded. Private wells are typically located on farms or hamlets away from the public distribution network. As they are not routinely monitored, users of private wells might not be aware of non-compliance with drinking water quality standards. In 2000, a measurement campaign of 628 private wells in Denmark found that 22% had nitrate concentrations above the drinking water standard of 50 mg L$^{-1}$ (Brüsch et al. 2004). This agrees very well with the results of using all available registered data in JUPITER, see figure 4(b). Given the monitoring practice in Denmark today, it is clear that with private well users, the largest group exposed to elevated nitrate concentrations in drinking water is at the same time the group with least monitoring and registered data on drinking water quality.

5. Conclusions and perspectives

Using four different approaches, it was found that 5.1%–7.2% of the Danish population was exposed to elevated nitrate
Table 4. Percentage of total, publicly and privately supplied Danish population exposed to nitrate from drinking water above 25 mg L\(^{-1}\), divided by methods (step 1–4).

| Year | Private wells | Public waterworks | Total |
|------|---------------|-------------------|-------|
|      | 15 | 31 | 35 | 34 | 39 | 31 | 43 | 37 | 41 | 37 |
| (1) by analyses | 19 | 21 | 19 | 19 | 13 | 11 | 7.7 | 6.9 | 4.9 | 4.8 |
| (2) by abstraction volume | 0 | 0 | 1.7 | 5.2 | 5.8 | 4.6 | 3.2 | 4.6 | 3.8 | 3.7 |
| (3) by Thiessen polygons | 9.5 | 14 | 9.5 | 10 | 7.0 | 6.5 | 4.5 | 3.8 | 3.3 | 3.1 |
| (4) by water supply areas | 10 | 10 | 11 | 9.3 | 3.5 | 3.6 | 3.1 | 3.0 | 2.4 | 2.5 |

Concentrations above 25 mg L\(^{-1}\) in 2012. For consumers connected to public supplies, the fraction exposed to elevated nitrate concentrations decreased in the last 35 years by 0.29 (0.23; 0.36) percent-points per year. This is suspected to be due to structural changes, as contrary to consumers of public water, the fraction of users of private wells exposed to > 25 mg L\(^{-1}\) nitrate in drinking water increased by 0.13 (0.00; 0.25) percent-points per year. Private well owners cannot easily take measures against non-compliance with the drinking water standard. In 2012, 37% of private well users were exposed to nitrate concentrations above 25 mg L\(^{-1}\), a considerably larger fraction compared to the users of public supplies. Virtually all of the 1.3% of consumers receiving water above the drinking water standard of 50 mg L\(^{-1}\) in 2012 were users of private wells.

The highest percentage of population exposed to elevated nitrate concentrations can be found in northern Jylland (for the public supply) and the whole of Jylland (for private wells), which can be explained by agricultural activities and high nitrate vulnerability of the groundwater magazines. Eastern Denmark has considerable lower levels.

Consumers of drinking water from private wells are the group exposed to the highest nitrate concentrations. At the same time, there is least information and monitoring for this group available. From an administrative perspective, private wells need more focus, as they supply the group that is exposed to drinking water quality often not complying with the legal limits. Monitoring and taking measures to avoid non-compliance with the drinking water standard is recommended, not only in regards to nitrate, but also other drinking water compounds such as pesticides and microbiological contamination (see Brüsch et al. 2004).

To our knowledge, this is the first time that all Danish water supply areas have been assigned the water quality parameters of the waterworks from which they are supplied and have been collected in one dataset. This makes it possible to use drinking water quality data from JUPITER to carry out epidemiological studies on an individual level when combined with the extensive Danish registers on health data and residential history. Within Denmark, there is a strong exposure contrast, making the nitrate data registered in JUPITER in connection with the public water supply areas a suitable database for an epidemiological study on the health effects of nitrate in drinking water. Thus, the so far equivocal question of nitrate in drinking water causing cancer (De Roos et al. 2003, Ward et al. 2005) might be answered on the base of a study population of over 5.5 million residents. However, special consideration has to be paid to the users of private wells, being the consumers with the highest exposure concentrations. Here, the already registered data is not sufficient and more effort is needed to acquire data from the municipalities and register them routinely in JUPITER.

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