Association between over-chlorinated drinking water and adverse reproductive outcomes in gilts and sows: a case report

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ABSTRACT: The present report describes a series of adverse events recorded in gilts and sows at a pig-breeding farm. The animals were listless, had poor appetite and dyspnea, sneezed and coughed, but were afebrile. Subsequently, an increased number of spontaneous abortions occurred, eventually rising to 50 times their average number. The usual infective causes of abortion were ruled out by diagnostic testing; however, the results of drinking water analysis pointed to over-chlorination, with a free chlorine residual concentration of 2.11 mg/l, caused by failure of the chlorinator dispenser connected to the water supplying system seven days previously. Analysis of data on reproductive parameters indicated that the over-chlorinated drinking water directly induced an increase in the number of abortions after only two days of consumption, whereas 7-day consumption of over-chlorinated drinking water had a direct delayed effect on the increased return to oestrus in gilts and sows, and on the increased percentage of stillborn piglets (all $P < 0.001$). The consequential indirect delayed effect manifested itself as a reduced number of farrowings in gilts and sows, and a lower total number of piglets born (both $P < 0.001$).

Keywords: reproductive failure; gilt; sow; watering; free chlorine residual

Drinking water for animals should meet the standards for animal welfare specified in two key points: the quantity available and the level of organoleptic, physicochemical and microbiological parameters. These points refer to the following two of five welfare standards: freedom from thirst and freedom from disease (Marjanovic and Tofant, 2008). Because drinking water must be such that its consumption or use does not endanger animal health, disinfection is vital for preventing the spread of diseases caused by waterborne pathogens (Tofant et al., 2008).

In most cases, chlorination is the primary method of disinfection and chlorine and its compounds are the disinfectants most commonly used for water disinfection. Effective water disinfection is achieved when the correct level of free chlorine residual is present in the water. When chlorine is added to water, free chlorine residual forms a mixture of hypochlorite ion and hypochlorous acid, which is a stronger disinfectant. The relative amount of each is dependent on the pH (Block, 1991).

The application of disinfection agents to drinking water reduces the microbial risk but poses a chemical risk in the form of disinfection by-products. The discovery that a large number of by-products are formed by the reaction of chlorine with naturally occurring organic materials raised concern about the potential health effects that might result from exposure to these compounds, of which trichalomethanes are generally the most prevalent (Richardson, 2003; Sadiq and Rodriguez, 2004; Hua and Reckhow, 2007; Tofant et al., 2008).

Early studies focused on oncogenic outcomes, while recent studies have mostly focused on reproductive defects. Reproductive health outcomes should be easier to study from the exposure point of view because of the shorter relevant exposure

period. Amongst others, birth weight, prematurity, spontaneous abortion, congenital anomalies and stillbirth have been the focus of these studies. There are still many problems to overcome because the results reported are inconsistent and inconclusive (Nieuwenhuijsen, 2005). Reproductive epidemiological studies have focused mainly on humans and laboratory animals, and to our knowledge, have not yet been conducted in farm animals.

This report describes a case of chlorine dispenser failure on a pig farm. The animals used water with a free residual chlorine concentration exceeding manifold the maximal allowable concentration. A possible association between adverse reproductive outcomes in gilts and sows and over-chlorinated drinking water was observed.

MATERIAL AND METHODS

Animals. The study was carried out at an intensive pig-breeding farm and included data on reproductive parameters of 1000 gilts and sows of Swedish Landrace, Large White, Pietrain breeds and their crossbreeds. The gilts and sows were accommodated in appropriate housing and microclimate conditions in all production facilities, service, prefarrowing and farrowing unit, and fed safe feed. They were artificially inseminated. For pregnancy testing, a traditional method of return to oestrus was used.

Watering system. The watering system consists of 150 m deep artesian well from which the underground water is pumped into a collection tank and through a piping system supplies the automatic drinkers. The quality of drinking water is systematically monitored at monthly intervals by an authorized laboratory of the National Institute of Public Health. The organoleptic, physicochemical and microbiological parameters are evaluated according to the Regulation on Drinking Water Safety (Anonymous, 2008). According to the regulations in force in Croatia, drinking water for animals should be of identical quality to that for humans. As water quality in terms of microbiological parameters may occasionally deteriorate, especially in the rainy season as in the case presented, a chlorinator is connected to the water supply for water disinfection.

Disinfectant. A commercial preparation, sodium hypochlorite with 10–15% of active chlorine was used as disinfectant. The disinfectant is dosed into the watering system to achieve a concentration of 0.1–0.5 mg/l of free chlorine residual in drinking water.

Case description. On October 2, 2005, the gilts and sows were observed to have become listless, had poor appetite, sneezed and coughed. Clinical examination revealed dyspnea, while their body temperature was not elevated. The first abortions occurred on October 3. On October 4, blood samples obtained from gilts, sows and boars, foetuses and respective placentas were referred to the Croatian Veterinary Institute. The usual causes of infectious diseases, leptospirosis, brucellosis and piglet reproductive and respiratory syndrome were ruled out by a diagnostic work-up. On the same day, a water sample was also referred for safety analysis. Results on organoleptic, physicochemical and bacteriological parameters, received on October 7, met the Croatian standards for drinking water (Anonymous, 2008), i.e., were acceptable in terms of safety, with the exception of the free residual chlorine level, which was 2.11 mg/l, exceeding manifold the maximum allowable concentration of 0.5 mg/l. This was related to the failure of a chlorine dispenser, which was put in operation on October 1 because of deterioration in bacteriological water quality due to the onset of the rainy season.

Statistical analysis. Statistical analysis was performed using the Statistica 8.0 (Statsoft Inc., 2008) software. Basic data processing was done using descriptive statistics methods. Distribution normality was tested by the Kolmogorov-Smirnov test. Student's *t*-test was used to compare the normal standard values (NSV) and chlorine affected values (ClV) of the reproductive parameters observed.

RESULTS AND DISCUSSION

The data used in this study report on the reproductive parameters of gilts and sows at the intensive pig-breeding farm collected from January 2005 to April 2006. This period was chosen to obtain the best possible insight into the values of reproductive parameters before, during (October 1–7, 2005) and after the toxic effects of over-chlorinated drinking water. As the toxic effects of over-chlorinated water on particular reproductive parameters manifested for a variable period of time, the number of months (*n*) taken to calculate mean NSV and ClV varied among the study parameters (Table 1).

As water quality on the farm does not usually meet the microbiological parameters during the

Table 1. Reproductive parameters of gilts and sows during the study period

Reproductive parameter	NSV		ClV		*P*-value
	n	mean ± SD	*n*	mean ± SD	
Number of spontaneous abortions	15	1.87 ± 1.41	1	91.00 ± 0.00	< 0.001
Return to oestrus number	11	65.91 ± 23.07	5	203.20 ± 65.09	< 0.001
Number of farrowings	12	204.17 ± 32.65	4	81.25 ± 33.47	< 0.001
Total number of piglets	12	2055.58 ± 387.43	4	777.25 ± 339.74	< 0.001
Stillborn piglet (%)	12	6.77 ± 1.60	4	12.57 ± 3.39	< 0.001

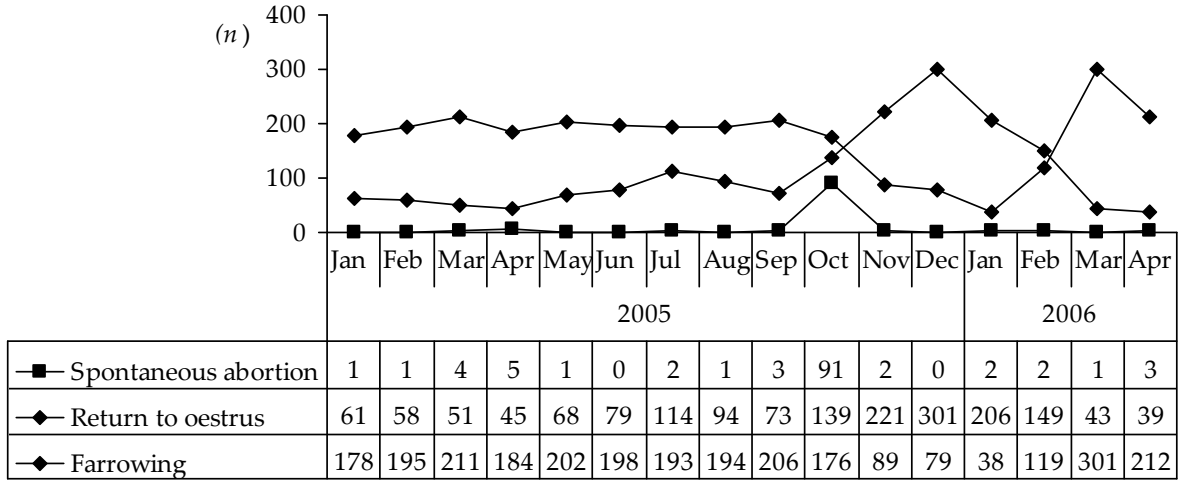
n = number of months taken into consideration for calculating mean NSV and ClV
NSV = mean standard values of reproductive parameters in months free from the toxic effect of water over-chlorination
ClV = mean values of reproductive parameters in months when the toxic effect of water over-chlorination manifested

rainy season in particular, water disinfection has been introduced as a measure to prevent hydric infections. In spite of concern about the formation of toxic by-products usually associated with its use, chlorine and its derivative sodium hypochlorite are still the most widely used disinfectants (Bodik et al., 2008).

Too much chlorine can be as detrimental as too little, so its levels must be monitored carefully. The major targets for the sub-chronic/chronic toxicity of chlorine in humans are the respiratory tract and blood. In animals, the major target organs are the immune system, blood, cardiovascular system and respiratory tract (Emmanuel et al., 2004).

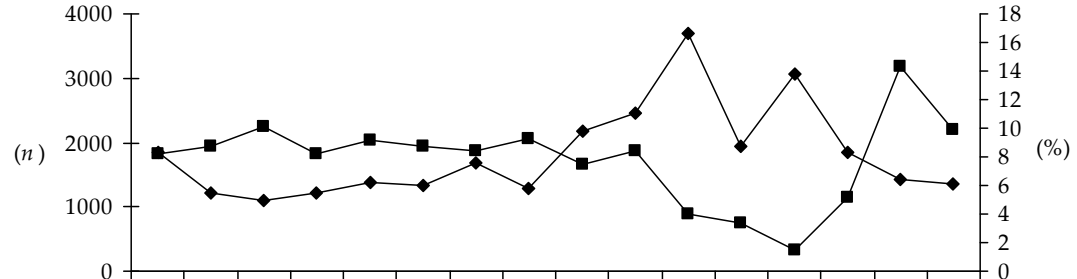
In this case, sodium hypochlorite was added to drinking water in an amount manifold exceeding the recommended dosage due to a failure of a chlorine dispenser, resulting in a higher water concentration of the free residual chlorine formed. Its toxic effect manifested itself on the reproduction of gilts and sows, readily observed as a significantly increased ($P < 0.001$), almost 50-fold (over normal) increase in the number of spontaneous abortions in October 2005. The aborted foetuses were consistent with gestational age and free from macroscopic pathologic alterations. Upon repair of the chlorine dispenser, i.e., after seven days of the pigs using water with the increased concentration of free residual chlorine, the water was safe for use again and the number of abortions returned to the usual number as early as November 2005 (Figure 1). The "normal" abortion rate in pig herds is 0.5–1%. These "normal" abortions are usually due to non-infectious causes. These may represent the termination of genetic errors during development (Rueff, 2000).

A direct delayed effect of 7-day over-chlorinated water consumption at the beginning of October



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Spontaneous abortion	1	1	4	5	1	0	2	1	3	91	2	0	2	2	1	3
Return to oestrus	61	58	51	45	68	79	114	94	73	139	221	301	206	149	43	39
Farrowing	178	195	211	184	202	198	193	194	206	176	89	79	38	119	301	212

Figure 1. Abortion, return to oestrus and farrowing number in gilts and sows during the study period



Total number of piglets	1826	1942	2245	1833	2045	1953	1883	2053	1659	1866	886	744	333	1146	3173	2189
Stillborn piglet	8.3	5.5	4.99	5.46	6.26	5.99	7.54	5.8	9.83	11.1	16.6	8.74	13.8	8.29	6.46	6.08

Figure 2. Total number of piglets and percentage of stillborn piglets during the study period

2005 manifested as a significant increase ($P < 0.001$) in the return to oestrus of gilts and sows over five months, from October 2005 to February 2006 (Table 1, Figure 1). This could be ascribed to conception failure due to the toxic effects of over-chlorinated drinking water, as well as to early embryonic mortality in the animals who conceived before and during the onset of toxic effects. The period from conception to around day 35 of pig pregnancy is called the embryonic stage. If all embryos die before this period, they will usually be resorbed. If more than four embryos remain alive, the female may go on to farrow normally. Early embryonic mortality, i.e., before day 14 (regular regression of *corpus luteum*), does not affect the length of the cycle which usually takes 21 days, and the female returns to oestrus at regular intervals. When the entire litter dies after day 14, the female returns to oestrus when the *corpus luteum* has regressed, and the length of the cycle is thus increased (embryonic mortality). The embryonic stage is followed by the foetal stage that lasts until parturition. Foetal death may result in abortion, mummification, maceration or stillbirth (Christianson, 1992; Ptaszynska, 2002; Givens and Marley, 2008).

In addition, the direct delayed effect of over-chlorinated water consumption manifested as a significantly higher percentage of stillbirths ($P < 0.001$) over four months, from October 2005 to January 2006 (Table 1, Figure 2). Stillborn piglets are those that are apparently normal but die shortly before or during parturition (Lucia et al., 2002).

The consequential indirect delayed effect of drinking water over-chlorination manifested as a significantly lower number of gilts and sows farrowing ($P < 0.001$) over four months, from November 2005 to February 2006 (Table 1, Figure 1) and a significantly lower total number of piglets ($P < 0.001$) born during the same period (Table 1, Figure 2). The piglets were weak and of lower body mass than usual. In animal studies of pregnancy exposure to disinfection by-products, reductions in birth weight have been commonly described after exposure to trichalomethanes, especially chloroform (Hinckley et al., 2005).

CONCLUSIONS

It is concluded that over-chlorinated drinking water was the cause of reproductive failure, increased number of spontaneous abortion, return to oestrus number and percentage of stillbirths, and reduced farrowing and total number of piglets in gilts and sows. Therefore, this report highlights the importance of free chlorine residual monitoring in animal drinking water, the safety of which may often be overlooked.

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