Available online at www.sciencedirect.com

SCIENCE DIRECT®

Science of the Total Environment 355 (2006) 135–144

Science of the Total Environment
An International Journal for Scientific Research into the Environment and its Relationship with Humankind

www.elsevier.com/locate/scitotenv

A survey of endocrine disrupting chemicals (EDCs) in municipal sewage and animal waste effluents in the Waikato region of New Zealand

A.K. Sarmah[a,*], G.L. Northcott[b], F.D.L. Leusch[c], L.A. Tremblay[c]

[a]*Landcare Research NZ Ltd., Private Bag 3127, Hamilton, New Zealand*
[b]*Hort Research, Private Bag 3123, Hamilton, New Zealand*
[c]*Landcare Research NZ Ltd., PO Box 69, Lincoln, New Zealand*

Received 30 August 2004; accepted 18 February 2005
Available online 7 April 2005

Abstract

We report the results of a recent survey of the concentration of natural estrogens (17β-estradiol, 17α-estradiol, estrone, estriol) and the synthetic estrogen, 17α-ethynylestradiol in representative animal wastes and sewage treatment plant (STP) effluents in the Waikato region of New Zealand. Dairy farm effluent samples showed high levels of estradiol (19–1360 ng/L) and its breakdown product estrone (41–3123 ng/L) compared with piggery or goat farm effluents. The combined load for these estrogens (excluding β epimer) varied from 60 to >4000 ng/L. The piggery effluent provided the lowest total estrogen load (46 ng/L), with estrone accounting for nearly 60% of the measured estrogens in this sample. The synthetic analogue, 17α-ethynylestradiol was detected only in one wastewater treatment plant sample, albeit at trace level. An estrogen receptor competitive binding assay was used to test the biological activity of the samples and confirmed that most agricultural waste samples contain high levels of estrogenic compounds. The potential of these wastes to cause endocrine disruption in the receiving ecosystem is unknown at present.

Keywords: Animal waste; 17β-estradiol; 17α-estradiol; Estrone; GC-MS; Estrogen receptor

1. Introduction

Global concern exists about the occurrence of endocrine disrupting chemicals (EDCs) in the freshwater environment and, their possible disruptive effects on indigenous fauna. A recent review by the World Health Organisation (WHO) stated the presence of estrogenic compounds in sewage water represented one of the best examples of linkage between effects and exposure to EDCs (Damstra et al., 2002). EDCs have been defined as "exogenous agents that interfere with the production, release,

* Corresponding author. Fax: +64 7 8584964.
E-mail address: sarmahA@LandcareResearch.co.nz (A.K. Sarmah).

0048-9697/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2005.02.027

transport, metabolism, binding, action, or elimination of the natural hormones in the body (of a human and/or wildlife species) responsible for the maintenance of homeostasis and the regulation of developmental processes" (Kavlock, 1999). Research interest in this area was stimulated by the discovery of compounds that produced biological responses similar to those of ovarian estrogens (e.g. estradiol), but now also includes a range of chemicals having androgenic and anti-androgenic properties (Mäkelä et al., 1999). The presence of both natural estrogens (17β-estradiol (E2) and its derivatives estrone and estriol) and its synthetic analogue (17α-ethynylestradiol) in treated wastewater effluents has been well documented (Purdom et al., 1994; Desbrow et al., 1998; Snyder et al., 1999, 2001; Belfroid et al., 1999; Hunag and Sedlak, 2001; Körner et al., 2001; Kolpin et al., 2002).

In addition, animal waste effluents have been found to contain large amounts of compounds (Shore et al., 1997; Wenzel et al., 1998; Raman et al., 2001; Shore and Shemesh, 2003) that may interfere with the normal functioning of endocrine systems, thus affecting reproduction and development in wildlife (Jobling et al., 1998; Hansen et al., 1998). For instance, concentrations as low as 1 ng/L of E2 (natural estrogen) led to induction of vitellogenin in male trout (Hansen et al., 1998). Elsewhere, Metcalfe et al. (2001) observed the formation of ova in the testis of Japanese medaka starting at concentration of 4 ng/L for E2 and 0.1 ng/L for 17α-ethynylestradiol. It has also been reported that alfalfa plants irrigated with sewage effluent containing steroid hormones displayed elevated levels of phytoestrogens (Shore et al., 1995).

Steroidal estrogen hormones such as E2, estrone and estriol contain a distinctive aromatic A-ring as part of their tetracyclic molecular framework (Fig. 1). Some properties of these compounds are given in Table 1. While all species of farm animals excrete these hormones, different species excrete different types and proportions of estrogens. For example, in cattle (*Bos taurus*) ≥90% of estrogens are excreted as 17α-estradiol, E2, and estrone as free and conjugated metabolites, while pigs (*Sus scrofa*) and poultry (*Gallus domesticus*) excrete E2, estrone, estriol and their respective conjugates (Erb et al., 1977).

New Zealand is a small country with numerous lakes, rivers and streams, a rapidly expanding dairy industry, and established beef, sheep, pig and poultry production. Pasture grass and farm animals dominate more than half the country's land surface, and affect nearly all catchments (Sarmah, 2002).

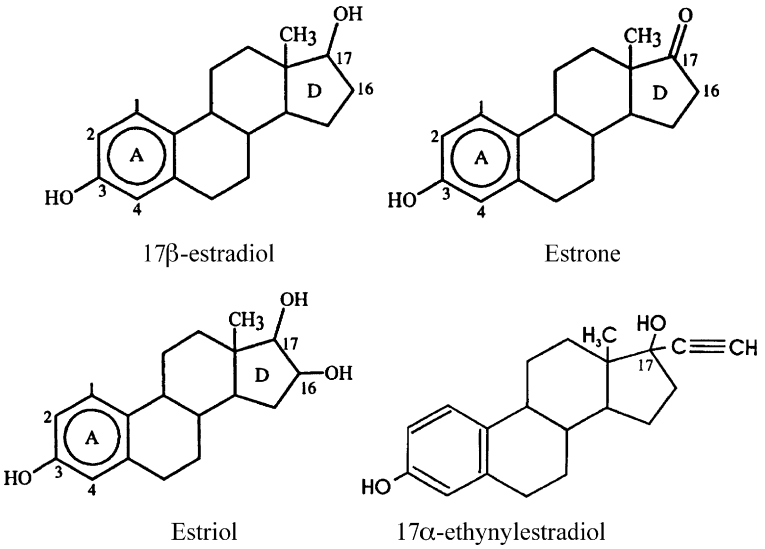

Fig. 1. Molecular structures of natural estrogen 17β-estradiol, its derivatives (estrone and estriol) and the synthetic analogue, 17α-ethynylestradiol (The letters and numbers indicate the ring assignments and carbon numbers, respectively).