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A SUMMARY OF SALINE INTRUSION PROBLEMS IN THE UNITED KINGDOM

Abstract

The principal areas affected by sea-water intrusion in the United Kingdom are industrial centres on the Mersey, Humber, Orwell, Stour and Thames estuaries. Several case histories are described briefly.

Over 70 per cent of groundwater used in the United Kingdom is pumped from the Chalk and sandstones of Triassic age. The Chalk is a fine-grained Cretaceous limestone, while the Triassic aquifers are typically fine to medium-grained sandstones. Groundwater flow in the Chalk is mainly through fissures but although fissure flow also predominates in the Triassic sandstones, intergranular flow is considered to be significant.

Saline intrusion has occurred where these aquifers have been heavily exploited for water supply near coastlines or estuaries containing brackish water. The cause is generally industrial abstractors concentrated in coastal sectors of major towns. The wells causing the intrusion are often sited very close to the coast. In many cases the volume of water pumped in a particular locality is limited by the chloride value and, if the rate of increase in salinity cannot be controlled, the wells eventually become disused. Therefore, the problem is to some extent self-correcting. Heavy abstraction near the coast associated with low pumping levels often serves to protect inland areas from more extensive intrusion of sea water.

The principal areas where saline intrusion has occurred are along the estuaries of the Mersey, Humber, Orwell, Stour and Thames at the centres and in the areas shown in Fig 1. In addition it has occurred locally at other centres around the coast, for example West Hartlepool and near Brighton. The aquifer involved at West Hartlepool, and probably also locally along the coast to be north for some 30 km, is the Magnesian Limestone of Permian age (1), otherwise the aquifers affected are the Chalk and Triassic sandstones. Several case histories are briefly summarised in the following paragraphs.

In Grimsby groundwater in the Chalk has been developed since the middle of the nineteenth century. By 1962 groundwater levels were below sea level in and around the town and over appreciable areas more than 5 m below sea level (2). As a result the salinity of the groundwater near the coast exceeded 250 mg/l in those areas where pumping was heaviest. Studies of the vertical salinity profile in wells in the town indicated that a wedge of saline water extended at least 2½ km inland. The saline water appears to be restricted to the less permeable parts of the Chalk and in some cases the inflow of saline water to individual wells only represents a small proportion of the total volume of water pumped. It has been suggested that in such circumstances the saline water could be pumped by a "scavenger" pump set in a well in the saline zone while fresh water is abstracted from a second pump placed above the saline interface (2).

To the east of London, along the Thames estuary, the Chalk, overlain in places by Tertiary sands, forms the coastline. The aquifer has been developed for industrial use and saline intrusion has occurred along both banks of the estuary. On the north bank the regional hydraulic gradient is away from the river because of overdevelopment of the resources of the Chalk and Tertiary sands where these aquifers are confined by the London Clay (3). The saline zone defined by the 150 mg/l isochlor is up to 4 km wide on the north bank. Near the river front extensive areas have values in excess of 500 mg/l. In general terms the saline water is moving laterally and vertically from the river in response to both local and regional hydraulic gradients. Because of the fissured nature of the Chalk, saline water may be more concentrated at particular levels in the aquifer and fresh water can occur below saline layers.

The problem of saline intrusion along the Mersey was commented upon as long ago as the middle of the nineteenth century (4,5). Since that time, with the steady increase in abstraction alongside the river, the extent of the intrusion has increased. The Triassic sandstones along both banks of the river are affected, and locally the chloride concentration exceeds 1000 mg/l as for example in Birkenhead, Liverpool and Widnes (6). Hibbert (7) in a study of the south bank of the river in the Wirral Peninsula, pointed out that the Ghyben-Herzberg principle did not apply, the saline interface being considerably below the level that would be anticipated from an application of the equation. This also applies on the north bank of the river where the interface is some 150 to 200 m below the surface in areas where groundwater levels are below sea level (8). In the

Wirral Peninsula the chloride content does not increase uniformly with depth. Although maximum values have been recorded at the greatest depth, minimum values are usually 30 to 45 m below the surface.

The Chalk outcrop of the South Downs forms the coastline of part of south-east England (Fig 1) and in this region the aquifer has been extensively developed for public water supply. Yields from individual wells are as high as 300 l/s. Locally saline intrusion has occurred as water levels have declined (9). Chloride values of more than 1000 mg/l were recorded in one well near Brighton, situated about 2640 m from the coast, at the end of the prolonged dry summer of 1949 (10).

Over the last 20 years the abstraction from individual wells has been related to seasonal variations in the amount of water stored naturally in the Chalk. This has involved pumping during the winter from wells situated near the coast or rivers to reduce the natural loss of water from the aquifer when this is high, and pumping from inland wells during the summer while at the same time limiting abstraction from coastal wells. During the summer, abstraction from coastal wells is controlled by the chloride content (11). This approach has increased the volume of water storage in the aquifer as a whole and considerably increased the annual volume of water that may be pumped from individual wells.

Hydrogeological studies are being made in the South Downs to determine the extent to which storage in the Chalk can be drawn upon during periods of drought. Mathematical models are being used to determine the ideal location of production wells and the relationship of abstraction rates to saline intrusion. The problem is complicated by the fissured nature of the Chalk and the fact that fissure density is greatest along the lines of narrow dry valleys in the aquifer. These zones of high transmissivity are potential areas for saline intrusion. In the next few years controlled pumping programmes will be carried out and the consequences assessed in a series of observation boreholes drilled along the coast.

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FIG1. MAIN AREAS
OF SEA WATER INTRUSION
IN ENGLAND AND WALES