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A study of soil loss and measures for its control in the mining areas of the middle Yellow River basin

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Abstract A detailed study of soil loss in the Shenfu Dongsheng mining area indicates that exploitation of the coalfield has had a significant effect in increasing soil loss. The proportion of the total waste material and slag from mining mobilized to the streams is 26.6-31.3%, and the annual increase in soil loss due to mining is 4300-5000 t km^{-2}. The main problems associated with the increased soil loss are the increased sediment loads entering the Yellow River, the aggravation of water pollution and an increase in land degradation and desertification. The measures used for controlling soil loss are mainly engineering measures which include revetment dykes, embankments, debris dams, and soil retaining dams.

INTRODUCTION

The middle Yellow River basin is located in the gullied Loess Plateau. Due to the adverse natural environment, soil loss in the areas is very serious. Mean annual soil loss exceeds 10 000 t km^{-2} year^{-1} over most of the area and reaches 30 000 t km^{-2} year^{-1} in some parts. In recent years, the extensive exploitation of coalfields has further aggravated the soil loss problem. The study area is situated in the contiguous areas of Shaanxi and Shanxi Provinces, and Inner Mongolia, where numerous coal mines have been developed. The coal-yielding area is about 30 000 km^2. There are four main tributaries of the Yellow River in the areas, i.e. the Kuyiehe, the Huangpuchuan, the Tuweihe, and the Gushanchuan. The annual sediment discharge of these four tributaries is about 220 million t, which represents 13.5% of the total sediment discharge of the Yellow River.

This paper considers four main topics as listed below:

(a) The types of erosion and their spatial distribution.
(b) The influence of mining on soil loss.
(c) The impact of soil loss from the mining areas.
(d) Measures for controlling soil loss.

THE MAIN TYPES OF SOIL EROSION IN THE MINING AREAS

The main types of soil erosion in the mining areas, involving exogenic processes, are water erosion, wind erosion and man-induced erosion (Fang Xuemin & Shi Mingli, 1990; Gan Zhimao, 1988). Water erosion takes place in the rainy season which extends from June to September (Table 1). Most soil loss in the areas is associated with water erosion, which includes splash erosion, surface erosion and channel erosion. Wind erosion, accompanied by sand storms, occasionally takes place in the dry season that extends from January to April. Man-induced erosion is primarily associated with accelerated erosion from the coal mine workings.

Table 1 Monthly precipitation, runoff and sediment transport at Wandaohengta gauging station, 1956-1986.

Month	Precipitation: (mm)	(%)	Runoff: (10^4 m^3)	(%)	Sediment transport: (10^4 t)	(%)
1	1.9	0.5	372	1.7	0.2	0.0
2	3.1	0.8	627	2.8	0.3	0.0
3	9.5	2.3	3791	16.8	34.3	1.1
4	16.6	4.1	1695	7.5	18.5	0.6
5	21.1	5.2	801	3.5	9.0	0.3
6	32.9	8.0	676	3.0	41.6	1.3
7	112.5	27.5	2723	12.1	852.7	26.7
8	123.8	30.1	5191	23.1	2139.0	66.9
9	56.9	13.9	2461	10.9	69.0	2.2
10	23.4	5.7	2059	9.2	20.4	0.6
11	6.7	1.6	1475	6.6	12.2	0.4
12	1.2	0.3	625	2.8	0.7	0.0
6-9	326.1	79.6	11051	49.1	3102.3	97.0
1-12	409.6	100	22496	100	3197.9	100

THE INFLUENCE OF MINING ON SOIL LOSS

Variation of flood sediment concentrations Taking one of the mining areas, the Shenfu Dongsheng coalfield, as an example, extensive exploitation of the coalfield began in 1986. By comparing similar floods before and after mining, a significant increase in flood sediment concentrations after mining is apparent (Table 2).

Variation of sediment grain composition According to measurements undertaken at the gauging stations, sediment grain size is currently coarser than that before mining commenced. This can be clearly seen by comparing the grading curves for years with similar amounts of sediment transport (Fig. 1). For the mining area, the grading curve for the period after mine development plots well below that for the period before development. The median diameter (d_{50}) is 0.23 mm after mine development and 0.047 mm before development (Fig. 1(a)). In the non-mining area, the results are much different (Fig. 1(b)). Both the

Table 2 Mean flood-period sediment concentration at Wandaohengta gauging station before and after mining development.

Period	Flood volume (10^4 m^3)	Sediment transport (10^4 t)	Sediment concentration (kg m^{-3})
Before mining			
28-29 July 1966	3107	2292	738
19-20 July 1972	2796	2675	957
30-31 July 1984	2818	1990	706
After mining			
21-22 July 1989	2500	2900	1160

Wandaohengta gauging station (Fig. 1(a)) and Xinmiao gauging station (Fig. 1(b)) are on the Kuyiehe River (Zhang Shengli & Shi Mingli, 1990).

Calculation of the increase in soil loss caused by mining Mining may cause large quantities of sediment to be carried by streams, either through direct dumping of waste into water courses or by erosion from waste piles. The area of the Shenfu Dongsheng coalfield is 2756 km^2. The development plan up

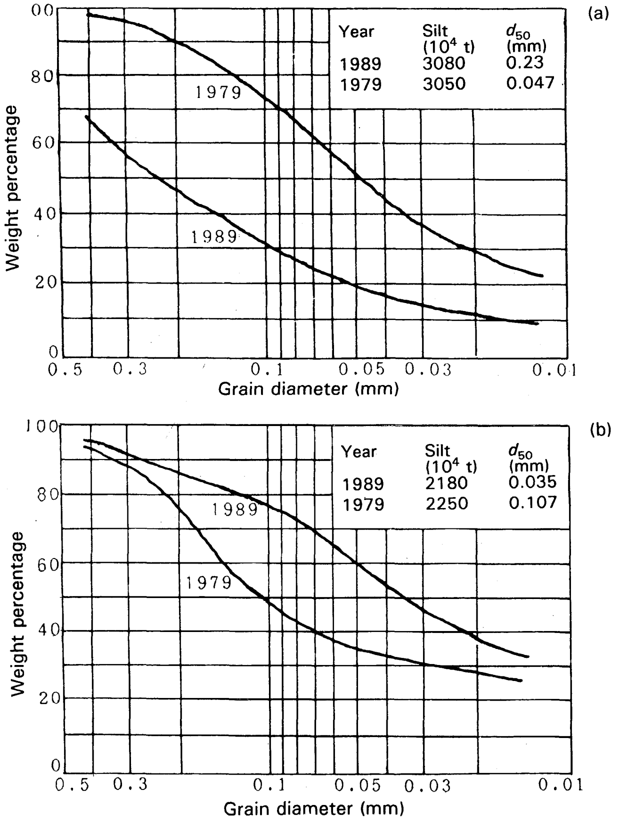

Fig. 1 Silt grading curves before and after mining: (a) Wandaohengta station in the mining area, (b) Xinmiao station in the non-mining area.

until the year 2000 has been separated into two stages. The first stage extends from 1987 to 1992. The second extends from 1993 to 2000. The total amount of waste material and slag, including waste from coal production, the transportation system, water and power supply, and civil construction, etc., is about 632 million t over the two stages. Based on analysis of typical sediment yield data, the proportion of the waste material and slag from mining reaching the streams can be estimated as 26.6-31.3%. The annual increase in soil loss is therefore 4300-5000 t km^{-2} during the two stages of construction (Fang Xuemin & Shi Mingli, 1990). The increase in soil erosion in the Shenfu Dongsheng coalfield is detailed in Table 3.

Table 3 The increase in soil loss caused by mining in the Shenfu Dongsheng coalfield.

Period	Total production of material waste and slag (10^4 t)	Proportion mobilized (%)	Total increase in soil loss (10^4 t)	Annual increase in soil loss (t km^{-2})
1987-2000	63182	26.6-31.3	16 806-19 776	4300-5000
1987-1992	17385	26.6-31.3	4624-5442	3300-3900
1993-2000	45797	26.6-31.3	12 182-14 334	5500-6500

THE IMPACT OF SOIL LOSS FROM THE MINING AREAS

Impact on the Yellow River Most of the material mobilized from the mining areas enters the Yellow River. The sediment is accompanied by soluble organic material, heavy metals and other toxic substances which also enter the Yellow River. The resultant increase in sediment concentration in the Yellow River produces an increased probability of hyperconcentrated density currents, increased bed accretion and aggravation of the flood hazard. The associated water pollution has an adverse affect on the natural environment of the middle and lower Yellow River basin.

Impact on production in the mining areas The impact of soil loss on the mining industry itself will mainly reflect two aspects. First, soil loss may change storm runoff conditions and cause an increase in flood peak discharges, thereby threatening the safety of the mining areas. Second, water and soil loss may influence water supply to the mining industry. The impact of soil loss on agricultural production is even more serious (cf. Fang Xuemin & Shi Mingli, 1990).

MEASURES FOR CONTROLLING SOIL LOSS

In the middle Yellow River basin, the mines are mostly located adjacent to gullies, on flood plains and in other low-lying areas. These mines are liable to suffer from flooding during storms. Measures employed for controlling soil loss should therefore also serve the function of flood prevention, and this is one of the main differences between control measures used in mine areas and in non-mine areas. The measures used for controlling soil loss are primarily engineering measures which include revetment dykes, embankments, debris dams and soil retention dams.

Revetment dykes are used to contain waste earth and slag tips, and they are suitable for both pit mines and gullies cast mines near gullies. Embankments serve the same function as revetment dykes but they are suitable for mines near a river and they have a greater capability for flood control. When selecting materials for constructing revetment dykes and embankments, cement-rubble masonry is preferable. Debris dams can be employed for mines producing large quantities of waste earth and slag, and their function is the same as the other two measures. The crest of a debris dam can also be used as an access route. After being filled with waste earth and slag, the area behind the dam can be used as an industrial site. The building materials used for debris dams are usually soil and grouted rubble, but soil is more common in the middle Yellow River basin. Soil-retention dams are suitable for regions other than mining areas and their main usefulness is for retaining flood water and sediment.

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