Asian Journal of Water, Environment and Pollution, Vol. 8, No. 3 (2011), pp. 59-66.

Old Coal Mine Workings Shaping to Cataclysm – A Study at Jharia and Raniganj Coalfields

Amar Prakash and K.B. Singh

Central Institute of Mining and Fuel Research, Barwa Road, Dhanbad - 826 015, India

✉ amar_cmri@yahoo.co.in

Received May 5, 2010; revised and accepted June 2, 2011

Abstract: Cataclysm of underground old/abandoned coal mine workings is a sudden subsidence which occur in the form of trough/discontinuous and pot-hole subsidence with extensive cracks. Rainfall, illegal mining operations and underground mine fires are the causative factors of subsidence. This paper deals with the different causative factors of subsidence and their impact on surface over old workings with precautionary measures of Jharia and Raniganj coalfields.

Key words: Subsidence, rainfall, pot-hole, mine fire.

Introduction

Subsidence is a time-dependent deformation of the subsurface ground, which is created by re-adjustment of the overburden above voids created by underground mining (Singh, 2007). Surface movement resulting from underground mining occurs in two phases, respectively termed active and residual subsidence. Active subsidence refers to all surface movements occurring simultaneously with the mining operations, while residual subsidence is that part of the surface deformation, which occurs following the cessation of mining. Residual subsidence is a major concern over abandoned mine lands (Karfakis, 1993). Subsidence is caused due to the disturbances of the old workings and these effects are difficult to segregate (Sinclair, 1963). Cracks, fissures, or step fractures (discontinuous), trough and pot-hole are the three basic forms of subsidence (Singh, 1992). All types are damaging to surface structures. Trough subsidence is expressed by a large depression with gentle slope. Pot-hole subsidence is expressed by an abrupt drop in the surface and has nearly vertical or belled outward walls. The occurrence of pot-hole subsidence is most often associated with old, abandoned, very shallow mines in places where the soil and rock strata of the overburden are incompetent (Bauer and Hunt, 1981). The frequency of subsidence is generally more during rainy season especially in the form of pot-hole. The depth of pot-hole is generally limited: 30m in Pennsylvania (Gray et al., 1977), 50 m in Illinois (Du Montelle et al., 1981) or 10 to 15 times seam thickness, based on studies primarily in Colorado, Utah and Wyoming (Dunrud and Osterwald, 1980).

Occurrence of subsidence over old workings of Jharia and Raniganj coalfields has been studied for one year with respect to climate and other phenomena. Subsidence phenomena, which occur in abandoned mines to a large extent, continue through years after mining (Littlejohn, 1979). A residual subsidence movement is dependent upon the presence of fire, small size pillars, pillar punching, geological disturbances, pillar robbing, dewatering and adjacent workings (Prakash and Singh, 2006; Prakash and Singh, 2009).

Role of Near Surface Geology

The soils and unconsolidated rocks near the surface tend to accentuate subsidence effects. The geologic materials

*Corresponding Author

are less homogeneous and isotropic than the underlying strata, and often behave in an inconsistent manner. Cracks and fissures may initially form in a 15 m thick layer from the surface (Singh and Kendorski, 1981). Later, these may be filled by plastic deformation or material transportation by water. Occasionally, however, water flow may accentuate these fissures and form gullies. Structures and renewable resource lands are thereby adversely affected.

The composition of the rock/soil cover is important; if the material is of a fine, sandy nature containing large amounts of water, it may flow to a rock fracture and drop into the underground workings. Besides water accumulating in the abandoned mine may seep upwards into the unconsolidated strata above through natural features and cracks in the rock and increase the potential for soil collapse.

Influence of Rain Water

Some correlation between amount of rainfall per month and the number of subsidence were studied in detail in Pennsylvania between 1971 and 1975 (Gray et al., 1977). The data of this study showed that 36% subsidence incidents had taken place in spring (rainy reason) and 9% taken place in late summer and autumn. There are several cases of land deformation due to influence of water (Kohl, 2001; Marschalko et al., 2008; Hartmann et al., 2004). Surface subsidence over underground mines can be caused by the piping mechanism, provided that certain basic requirements are met. These are (1) an easily erodible unit overlying the mine void, (2) an adequate source of water that has access to the erodible material positioned so that flow can occur and (3) a conduit or channel-way that allows the hydraulic transport of erodible material into the mine reservoir (Allen, 1969). Water reduces the strength and stiffness of pillars and the roof and floor markedly. Periodic changes in mine humidity, results in promoting deterioration of all these factors. Floor softening permits punching resulting in instability and subsidence. Flow through fissures cause seepage pressures, endangering the stability of the rock mass. Cleavage and bedding planes are lubricated by water including movements.

The cavity originates at the point of water entrance into the channel-way. It enlarges as additional soil is removed assuming an approximately hemispherical shape. Growth of the cavity continues as entering ground water erodes from the periphery of the cavity creating tensional stresses in the overlying sands and gravity collapse. The collapsed sand is continually removed by flowing water. The process continues until equilibrium is achieved, i.e., water flow is insufficient to transport soil particles. Surface collapse is possible if the cavity diameter exceeds the strength of the surface capping. Earth shocks or tremors can trigger failure of the capping as can loss of soil strength by saturation (Allan et al., 1981).

Case Studies

Subsidence studies were carried out over old and abandoned workings of Jharia Coalfields (JCF) and some portion of Raniganj Coalfields (RCF) in 2008. Annual precipitation data was collected from Indian School of Mines University, Dhanbad. There were thirty-one cases of subsidence in the form of pot-hole and discontinuous/ trough in the year 2008 (Figure 1) with annual precipitation of 111.35 cm out of 31 cases, sixteen cases were of discontinuous/trough type (Table 1) whereas fifteen cases were pot-holes (Table 2).

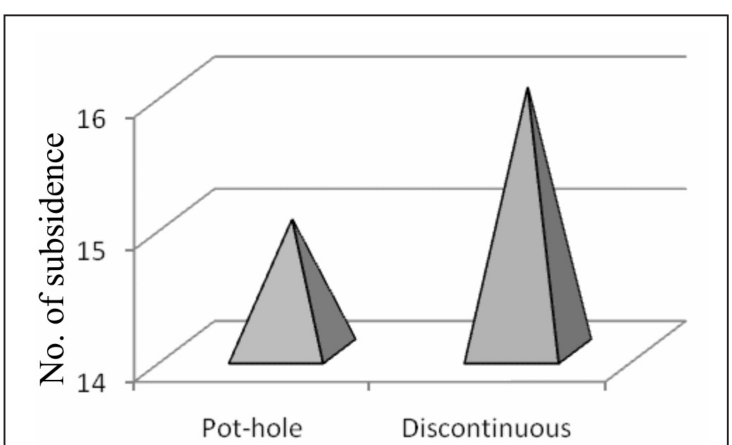

Figure 1: Types of subsidence occurred over old workings.

Table 1: Discontinuous subsidence over old workings in 2008

Sl. No.	*Location*	*Date of subsidence*	*Cause*	*Impact*
1	B. P Incline, Mugma, ECL near Mochikting (RCF)	19/05/2008	Illegal mining	Development of cracks within 500 m^2 area
2	Rajrappa Project, CCL	05/06/2008	Rain water entered in mine and roof collapsed + illegal mining	4 persons killed
3	Kalubathan OP area in Palsia Village, Nirsa (RCF)	15/06/2008	Illegal mining	6 persons injured
4	Victory patch, Bastacola colliery (JCF)	19/06/2008	Illegal mining	4 persons killed due to illegal mining
5	Salanpur, near Ruidas para, Asansol (RCF)	19/06/2008	Rainfall	Huge cracks developed ranging to a length of 800m. 80 houses damaged, 26 people injured. Area was declared unsafe by the management.
6	Bright Kusunda Kali temple, Dhansar (JCF)	08/07/2008	Rainfall	24m × 30m area subsided, strata standing on few pillars.
7	Patherdih colliery No. 6 pit (JCF)	14/07/2008	Rainfall + illegal mining	Cracks developed on road going to Main Colony and near houses due to collapse of seam no. 8.
8	Huchuktand basti, No. 6 Industry colliery (JCF)	26/07/2008	Rainfall + mine fire	Developed huge cracks in 12 houses and on ground surfaces emitting pungent smelling gases. This area already experienced subsidence earlier.
9	Shabri nagar, near Modidih colliery (JCF)	28/07/2008	Rainfall + mine fire	Declared as danger zone in May 2007. Cracks developed on walls of 6 houses and ground surface (15 m length) had great opening depth.
10	Huchuktand basti, Industry colliery (JCF)	28/07/2008	Rainfall + mine fire	Complete basti affected. Gas emission and cracks developed in houses and ground. Few people vacated the houses and faced difficulty to take shelter due to rain. Area was declared danger zone in May 2007.
11	Shabri nagar, near Modidih colliery (JCF)	30/07/2008	Rainfall + mine fire	Subsidence continued at the same place which occurred on 28/07/2008. Several other houses got damaged, new cracks formed on ground surface. Earlier damaged houses further got affected by enlarged openings of existing cracks.
12	Bhagatdih, Ena Islampur area, near Jharia-Dhanbad main road (JCF)	28/08/2008	Rainfall	Cracks on few houses, wall collapsed. Subsidence prone area.
13	Marwa village, on main road going to village (RCF)	30/08/2008	Illegal mining	Developed cracks on the steps made round the periphery of pond.
14	Machi cutting mine, Mugma area (RCF)	06/09/2008	Illegal mining	Mine entrance collapsed, 6 persons killed and 2 injured.
15	22/12 basti, Modidih colliery, Sijua area (JCF)	24/09/2008	Rainfall	Developed cracks in houses. Movement started on 22/09/2008. Ground was not stable causing fear of living to the local people.
16	Between Shasan beria and Marwa basti, Nirsa (RCF)	24/10/2008	Illegal mining	Pond bund broke and water entered into the mine through cracks.

Table 2: Pot-hole over old workings in 2008

Sl. No.	*Location*	*Date of pot-hole formation*	*Pot-hole dimension (m)*		*Cause*	*Impact*
			Dia.	*Depth*		
1	Banihir, Indira chowk, Jharia-Sindri main road (JCF)	05/07/2008	0.60	—	Rainfall + mine fire	60 years old working under fire. Earlier in 1998 and 2001 pot-holes occurred in this area. Vehicle movements affected, gas emission became the matter of concern for the local people.
2	Ekra hari patti, Loyabad (JCF)	09/07/2008	1.50	30	Rainfall	Gas emission and risk of falling of people into the pot-hole.
3	Rise area, Industry colliery (JCF)	09/07/2008	4.50	—	Rainfall	Risk of living in the area.
4	Shiv temple, Lodna (JCF)	14/07/2008	4.50	—	Rainfall	Water entered into the mine through pot-hole inundating the neighbouring mines.
5	Tisco Jamadoba washery (JCF)	16/07/2008	1.50	—	Rainfall	Fear of residing in the area.
6	Behind Modidih hospital, Jogta More (JCF)	19/07/2008	1.30	4.50	Rainfall	Fear of residing in the area.
7	Behind Modidih hospital, Jogta More (JCF)	26/07/2008	4.50	10.50	Rainfall	Subsidence prone zone. People were told earlier to quit the place.
8	Karkendra-Katras main road, near Ekra bridge (JCF)	16/09/2008	0.30	—	Rainfall	Vehicle movements stopped.
9	Bansjora (JCF). (2 Nos.)	22/09/2008	7.50	—	Rainfall	Fear of residing in the area.
10	22/12 basti, Modidih colliery, Sijua area (JCF)	22/09/2008	1.30	60	Rainfall	Fear of residing in the area.
11	Nirsa-Kalubathan road (RCF)	22/9/2008	1.50	—	Rainfall	Vehicle movement obstructed. One person, driving cycle, fell in pot-hole.
12	Lodna-Bagdigih road (JCF)	22/9/2008	1.50	—	Rainfall	Vehicle movement obstructed.
13	Chothaikuli Dharmnagar (JCF)	7/10/2008	1.00	—	Rainfall + fire	A 60 year old lady fell into the suddenly developed pot-hole. A similar incidence took place in 1997 when a 14 year old girl fell into the pot-hole.
14	Rajput basti, Godhar (JCF)	9/10/2008 11/10/2008 13/10/2008	2.40	—	Rainfall	Cracks developed in nearby houses, with emission of gas from pot-hole. Mining was done in 1918 and is in fire. Subsidence took place in the same area on 17/7/2007 and 22/9/2000. Subsidence continued for 4 days. Pot-hole diameter widened up to 4.2 m

Pot-hole form of subsidence is common in shallow old workings, especially during rainy season. The pot-hole formations varied in dimensions ranging from 0.6 m to 7.5 m in diameter. Subsidence due to illegal mining and fire are generally in discontinuous form. This type of subsidence affects larger surface area and its intensity is massive causing severe damage to the surface structures. It is evident from Modidih case that one time subsidence is not an indication of well settled/and stable ground. Similar study has also been done elsewhere (Prakash et al., 2005; Anon, 2007) by the mind tank, Central Institute of Mining and Fuel Research, Dhanbad for one year after the occurrence of triggered subsidence. Modidih was the most affected area in 2008.

Rainfall recharges the overburden strata, which decreases the strength of the rocks. This phenomenon increases the pore pressure, which can trigger roof fall. The roof fall may propagate upward resulting in the formation of pot-holes on the surface. Recharge of the overburden can also increase erosion of the weak and weathered sandstones due to movement of water along closely spaced joints and faults which can also result in the formation of pot-hole on surface. Rainfall is closely related to the occurrence of pot-holes (Singh, 2007).

The correlation coefficient between subsidence and rainfall is 0.86 (Figure 2). The amount of rainfall was 86.9% in July, August and September, 2008 and the number of subsidence was 74.1%. The association between rainfall and subsidence is cumulatively shown in Figure 3. Hence, rainfall plays a vital role for triggered subsidence. The causes of subsidence over old workings are mainly underground fire, rainfall and illegal mining. Out of total number of subsidence, 61% was from rainfall where as 26% and 13% was from illegal mining and mine fire (Figure 4). Fifteen number of subsidence took place with annual precipitation of 525.86 cm in the year 2007

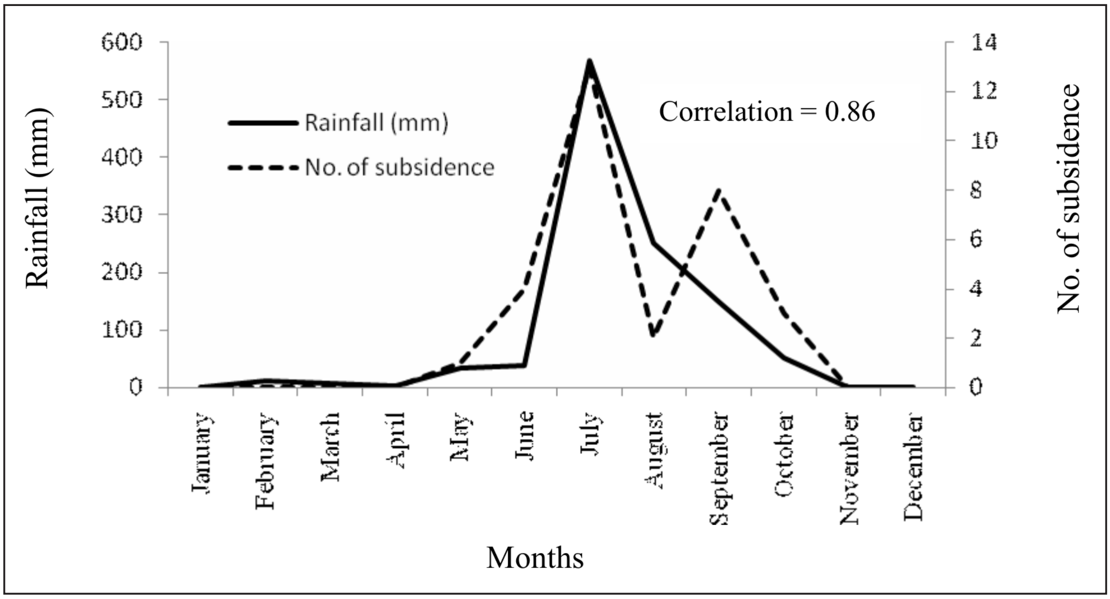

Figure 2: Correlation between rainfall and number of subsidence.

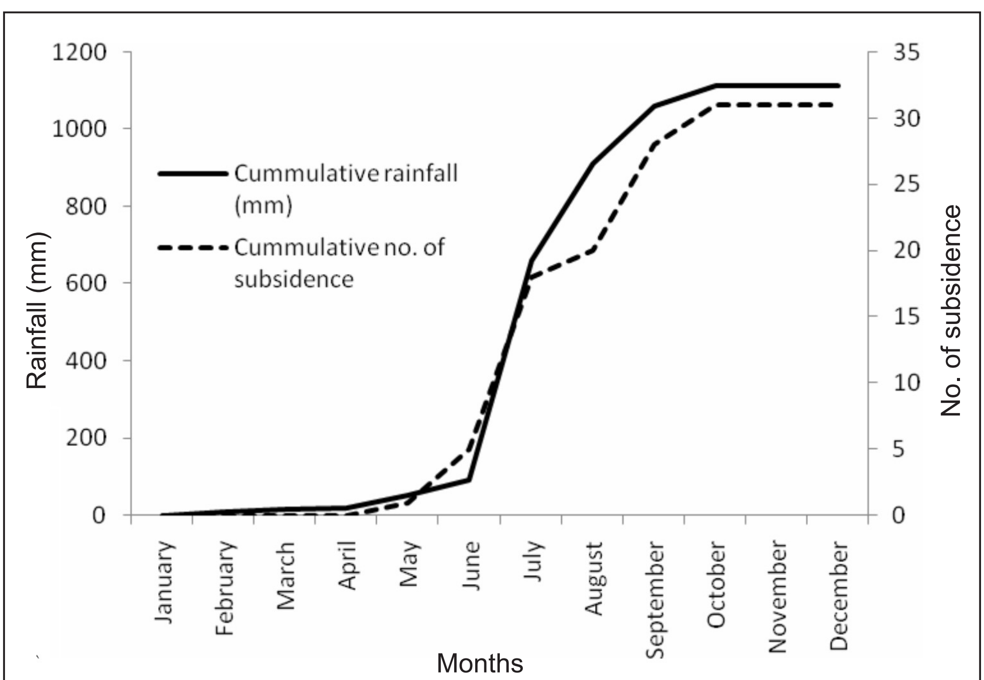

Figure 3: Cumulative rainfall and subsidence relation for the year 2008.

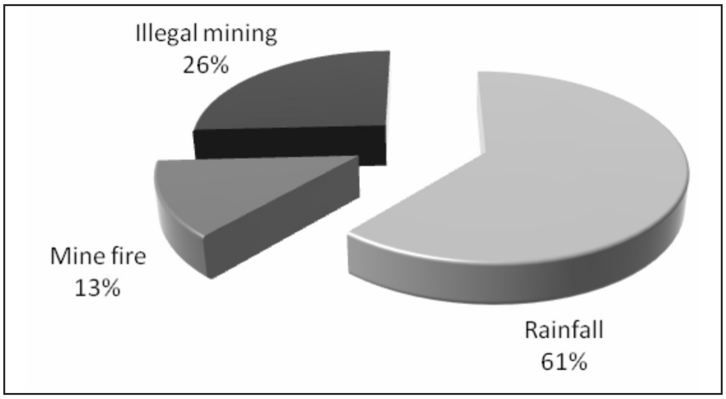

Figure 4: Subsidence percentage due to rainfall, mine fire and illegal mining.

in Jharia and part of Raniganj coalfield. The amount of rainfall was 86.5% in August and September 2007 and the number of subsidence was 73% (Prakash, Lokhande and Singh, 2010).

Impacts of Subsidence

In Jharia Coalfield, 595 locations are in the grip of fire and land subsidence. Discontinuous/trough subsidence over old workings leads to development of cracks with openings, dimensions depending upon the intensity and magnitude of subsidence. It envelopes large surface area causing damage to surface features like roads, buildings, temples, etc. 98 houses were damaged, 10 persons killed and 38 injured due to subsidence in 2008 in Jharia and Raniganj coalfields. Discontinuous/trough subsidence led to severe damage to surface features by causing collapse of houses with development of severe crevices on walls and floors (Figure 5). Cracks developed on roads affected the movement of the vehicles. Breathing of air in the mine through surface openings further deteriorates underground mining conditions. Damage of pond bund led to mine inundation through surface cracks. Emission of pungent and poisonous gases due to underground mine fire caused ill effect to the people residing in its vicinity.

Pot-hole formations are fatal as it does not impart any prior indication of its occurrence. The opening of pot-holes are hazardous to social life in the form of risk of falling in the pot-holes, inflow of surface run off into the mine, outflow of mine water at the surface and emission of huge amount of mine gases. Vehicle movements were affected at several places due to development of pot-holes on roads.

Mitigative Measures

The mitigative measures are limited owing to inapproachability of old workings. Surface sealing, inundation and remote sealing (Banerjee, 1985) are the techniques to deal with long standing fires in old and abandoned workings. Application of inert gas (Grever, 1974), degasification (Chugh, 1982) and fly ash packing (Sinha and Malhotra, 1982) can also prevent and control fire. Filling of voids (point support and areal backfilling methods) (Lokhande et al., 2005) can enhance the residual strength of supporting pillars. Mine filling and sealing of mine entrances will avoid illegal mining operations. Bharat Coking Coal Limited located 79 illegal mining places in Jharia Coalfield, out of which 25 places have already been sealed off by the management. Similar action was taken by Eastern Coalfield Limited, in which eight locations have been sealed out of 23 illegal mining sites.

Surface cracks developed due to subsidence must be filled with soil/sand to avoid inflow of water which is

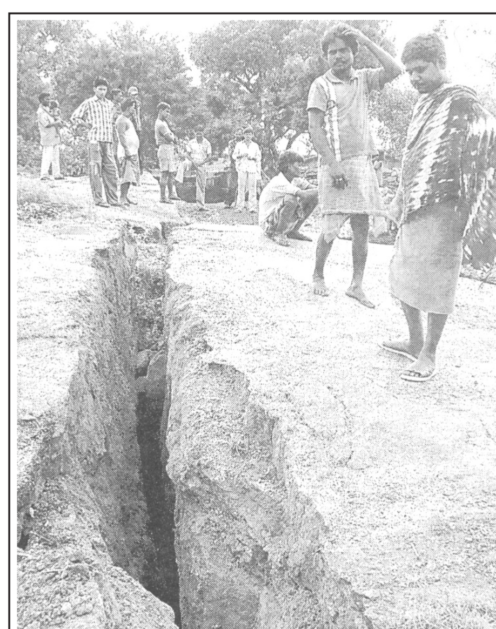

Figure 5: Discontinuous subsidence at Bright Kusunda.

dangerous in developing pot-holes and washing away of stowed sand fills from its original place. During rainy season, water should be kept out of partly subsided areas; it may loosen sand or clay and cause surface movement, resulting in further underground subsidence.

People residing in mine fire areas and over old workings, especially at shallow depth, have to leave the place. As per Jharia Action Plan, there is a proposal to develop nine satellite townships for the people residing in subsidence and fire prone areas. At Belgaria, development of a township is in progress as a pilot project.

Conclusion

Subsidence over old workings due to natural calamity like rainfall and underground mine fire cannot be overlooked. Rainfall, illegal mining and mine fires contribute 61%, 26% and 13% respectively incidents of subsidence in 2008 in Jharia and Raniganj coalfields. The number of subsidence accelerates during rainy season. Hence, rainfall is the most important causative factor. Sudden subsidence is always severe to surface structures which caused damaged to 98 houses, roads etc. It is also hazardous to social life which led to 11 fatal and 38 injuries. Pot-hole subsidence is very dangerous as it does not give any prior indication of occurrence. Hence, it is imperative to take mitigative and precautionary measures for the safety of social life in subsidence prone areas.

Acknowledgement

The authors are thankful to the Director, Central Institute of Mining and Fuel Research (erstwhile CMRI), Dhanbad, for granting kind permission to publish this paper. The views expressed in this paper are those of authors and not necessarily of the organizations they represent.

References

Allan, M.J., Ralph, J.H. and E.F. Gorden (1981). Piping induced subsidence over an underground mine. *Proceedings workshop on surface subsidence due to underground mining*, 30 November. Lakeview Inn and Country Club Morgantown, W.V., 268–273.

Allen, Alice S. (1969). Geological settings of subsidence, *Reviews in Eng. Geol II*, *Geol. Soc. Am.*, 305–342.

Anon (2007). Report on safety evaluation of surface structures lying over subsided Sanctoria village at Sodepur area of ECL, Unpublished Central Institute of Mining and Fuel Research, Dhanbad, 1–14.

Banerjee, S.C. (1985). Spontaneous combustion of coal and mine fire. Oxford & IBH Publishing Co., 125–139.

Bauer, R.A. and S.R. Hunt (1981). Profile, strain and characteristics of subsidence from coal mining in Illinois. Proceedings Workshop on Surface Subsidence due to Underground Mining, 30 November. Lakeview Inn and Country Club Morgantown, W.V., pp. 207–218.

Chugh, J.C. (1982). Role of degasification in spontaneous combustion in coal mines. Combating Coal Fires, edited by Singh B., Parijat Mudranalaya Publications, 70–76.

Du Montelle, P.B. et al. (1981). Mine Subsidence in Illinois: Facts for the homeowner considering insurance, *Environmental Geology Notes*, Illinois Geological Survey Division, Champaign, IL, report IL-SGS, August, p. 30.

Dunrud, C.R. and F.W. Osterwald (1980). Effects of coal mine subsidence in the Sheridan, Wyoming area, professional paper, No. 1164, *US Geological Survey*, p. 55.

Gray, R.E., Bruhn, R.W. and R.J. Turka (1977). Study and analysis of surface subsidence over mined Pittsburgh coalbed. *Final report for US Bureau of Mines*, Contract No. J0366047, July, p. 145.

Grever, R.E. (1974). Study of mine fire fighting using inert gases, Department of the Interior, Bureau of Mines, Washington, DC, BU Mines OFR 15–76, p. 212.

Hartmann, J., Okada, N. and J.K. Levy (2004). Integrated disaster risk management strategy to prevent exposure to hazardous substances due to inundation triggered subsidence releases: A concept for Japan. *Journal of Natural Disaster Science*, **26(2):** 87–93.

Karfakis, M.G. (1993). Residual subsidence over abandoned coal mine. *Comprehensive Rock Eng*, edited by Hudson J.A. **5:** 451–476.

Kohl, M.S. (2001). Subsidence and sinkholes in East Tennessee, Nashville. Tennessee, pp. 1–11.

Littlejohn, G.S. (1979). Consolidation of old coal workings. *Ground Engineering, England*, **12(2)**: 22–30.

Lokhande, R.D., Prakash, A., Singh, K.B. and K.K.K. Singh (2005). Subsidence control measures in coalmines: A review, *Journal of Scientific & Industrial Research*, **64:** 323–332.

Marschalko, M., Fuka, M. and L. Tieslin (2008). Influence of mining activity on selected landslide in the Ostrava–Karvina Coalfield. Acta Montanistica Slovaca, Rocnik 13, Cislo 1, pp. 58–65.

Prakash, A. and G. Singh (2006). Land degradation due to pothole subsidence. *MINENVIS*, No. 50, September, pp. 1–15.

Prakash, A. and K.B. Singh (2009). Subsidence in Abandoned Mines: A Review. *Journal of Indian School of Mines, An International Journal*, October, **IV(1):** 55–66.

Prakash, A., Lokhande, R.D. and K.B. Singh (2010). Impact of rainfall on residual subsidence in old coal mine workings. *Journal of Environmental Science & Engineering*, **52(1):** January, 75–80.

Prakash, A., Singh, K.B., Kumar, A. and R.D. Lokhande (2005). Residual subsidence over abandoned mine: A case study. *Mining Engineers' Journal*, **7(1):** August, 17–21.

Sinclair, J. (1963). Ground movement and control at collieries. Published by Sir Isaac Pitman & Sons Ltd., London, 33 pp.

Singh, K.B. (2007). Pot-hole subsidence in Son Mahanadi Coal Basin. *Engineering Geology*, **89:** 88–97.

Singh, M.M. and F.S. Kendorski (1981). Strata disturbance prediction for mining beneath surface water and waste impoundments. Proceedings 1st Conference on Ground Control in Mining, West Virginia University, Morgantown, WV, pp. 76–89.

Singh, M.M. (1992). Mine subsidence (Chapter 10.6) in SME Mining Engineering Handbook, SME, 938–971.

Sinha, P.R. and K.K. Malhotra (1982). Combating old and extensive fire in the Jharia coalfield with special reference to Jogta fire. *Combating Coal Fires*, edited by B. Singh, Parijat Mudranalaya Publications, 85–92.