EXTERNALITIES OF GROUNDWATER CONTAMINATION DUE TO POLLUTION AND EFFECTS ON HUMAN AND ANIMAL HEALTH IN KARNATAKA

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Abstract

In this study, negative externality due to distillery pollution on agriculture in Kabini command in Nanjanagudu taluk, Mysore District is estimated. The spent wash let in lagoons enables settling heavy metals to infiltrate soils, gradually affecting soil and health. The distillery opened during 1985 and farmers apparently began experiencing the negative externalities due to pollution from 1995. The groundwater extracted for irrigation was the first victim of distillery pollution rendering it unfit even for irrigation purposes. Paddy, sugarcane, Banana, Jowar, Mulberry, Coconut, Ragi are the major crops being grown in this command area.

For this study, all the 35 distillery pollution affected farmers in the Distillery Dffluent Polluted Villages (DEPA, comprising Geekalli, Goluru) are selected. As a control, 35 farmers who were located in Devarasanahalli in the Kabini command area, but who are away from the distillery pollution area are studied.

The major effect of groundwater pollution is the downward shift in sugarcane area due to pollution to the tune of 60 percent in DEPA. Area under paddy did not alter after pollution. Thus, farmers considered paddy to be the only crop which can tolerate / withstand, pollution levels. Crop diversity in terms of area under crops like tomato, ragi, jower, cucumber and banana increased in DEPA as the farmers shifted from sugarcane. In the control village, major crops grown are paddy and sugarcane due to assured supply of good quality of water through out year, and these occupied 20 and 50 per cent of the area respectively.

In DEPA, all drinking water wells were abandoned and 22 (8) percent of open wells (bore wells) are abandoned. Farmers in DEPA (control village) realized net return per acre of Rs. 5489 (Rs.10892), a reduction of 98 percent due to distillery pollution. As the net return from different crops in DEPA are far lower than control village, farmers in DEPA had to search for new opportunities and with the result their off farm income was Rs 11142 per family as against Rs 3571 in control village. In DEPA, farmers realized net return from sugarcane of Rs 2954 per acre cultivated using poor quality irrigation water as against Rs 26,249 in control village.

In DEPA, due to polluted groundwater use, farmers are suffering from allergic dermatitis, skin irritation, vomiting sensation, stomach pain and eye irritation. Thus, an additional health expenditure of Rs 1992 was incurred per family per annum on these. The net return per acre for farmers located closer to (away from) lagoon and canal irrigated area was Rs. 4859 (Rs. 6227) a reduction of 22 percent; similarly repair charges of pumpset was Rs. 2500 (Rs. 937), an increase of 167 percent. As the distance from canal increased the net return decreased. This shows that the canal water helped in ameliorating pollution hazards but not to a significant extent. As the Electrical conductivity increased the net returns decreased.

In DEPA there was a 49 per cent reduction in sugarcane yield, 27 per cent in paddy, and 75 per cent in tomato. The loss of human labour days due to health damage resulting from

distillery pollution was about 18 days. As a result farmers incurred an opportunity cost of Rs 900 per annum.

These are distinct pointers of the effect of distillery pollution effluent on agriculture. Net loss per acre of paddy (sugarcane) in DEPA is Rs 2656 (Rs 16840). The DEPA farmers richly deserve to be subsidized for this loss.

Key words: Distillery effluents, negative externality, groundwater pollution, health costs

Introduction

Industrial pollution has been one of the most important factors causing water pollution. Industries spew effluents into water bodies containing chemical and biological matters that impose high demands for oxygen. Apart from this industrial wastes contain chemicals and heavy metals that are harmful to human health and ecosystem. Polluted water has serious impact on land productivity when it is used for irrigation. The study of environmental problems in the agricultural sector due to industrial pollution is an inter sectoral problem which has to be given due importance.

Use of poor quality water is a slow poison for all forms of life as it increases salinity, ion toxicity and infiltration problems in soil besides it also brings about ecological changes in the biological properties of soil. These affect crop production and reduce farm income.

This study is an attempt to address the economic and environmental effects of poor quality water on crop production and human health. This study pertains to Kabini command area in Nanjangud taluk of Mysore district. The study area is affected by a point pollution source, which is a distillery unit. Distilleries are one of the most important agro based industries producing ethyl alcohol for industrial and potable uses. They also assume importance due to growing requirement of alcohol in every sector. However, their environmental significance is assessed as pollutional units generating large volume of foul smelling and colored wastewater known as spent wash.

Distillery effluent is characterized by its extremely large volume, foul odour, dark coffee color, highly biodegradable character, dissolved solid content that presents significant disposal or treatment problems. The characteristics of distillery effluents amply indicate the immanent threat to soils, crops and water resources (Table A).

Table A: Characteristics of distillery effluent

Parameters	Spent wash	Post-methanation effluent
BOD (mg/lt)	28000-50000	4000-5000
COD (mg/lt)	90000-100000	20000-25000
Nitrogen (mg/lt)	1000-2000	260-300
Potassium (mg/lt)	9000-13000	6000-7000
Phosphorus (mg/lt)	30-50	18-20
Sulphate (mg/lt)	1200-3000	800-1000
EC (ds/m)	15-36	8.5-23
pH	3.5-4.5	7.5-8

Note: Postmethanation is spent wash after treatment. The data pertains to distillery units using molasses for alcohol production.

Source: Joshi, H.C, Pathak, H., Choudhary, A. and Kalra, N., 1996, Distellery effluent as a source of plant nutrients, prospects and problems. Fertilizer News, 41:41-47.

The spent wash is stored in large lagoons, which were unlined from 1985 till 1995. The characteristic of the soil being red sandy loam, the effluents percolate into the soil contaminating soil and groundwater. The farmers have access to surface water through Kabini canal. But the canal water is available only for six months between July to December. Farmers depend on groundwater for irrigation during the remaining season. In recent years contamination of groundwater has emerged as a severe environmental issue in the locality due to percolation of spent wash from lagoon to the groundwater. This has affected the prospectus of agriculture, health and environment in that region. Consequent to use of polluted groundwater for irrigation farmers are incurring heavy losses in agriculture due to use of polluted groundwater.

Objectives of the study

This study based on field data from Nanjangud taluk, Mysore district, Karnataka, has been conducted with the following objectives:

1. Estimation of damage function due to groundwater pollution on the farm economy.
2. Institutional analysis of property rights and law in addressing the predicament.

Approach

Kabini command area in Nanjangud taluk, Mysore district, Karnataka has housed at least 21 industries *inter alia* distillery (Gemini distillery), pharmaceuticals (Max Pharma), textiles, instant coffee (Nescafe), sugar factory (Bannariamman sugar factory), aluminum foil factory etc. Among these industries, the distillery was letting out effluents to the lagoons affecting agricultural production in different villages and over at least 15 years since 1985. The Department of Soil Science and Agricultural Chemistry, UAS, Pollution Control Board, Bangalore and the Department of Agriculture, Nanjangud taluk have been reporting the toxic effects of effluents of distillery on agriculture and health in Geeka halli, Goluru, Mulluru, and Kodi Narasipura. A reconnaissance survey of this area was undertaken during Dec 2002 to gain insight into the problem. The affected farmers explained their predicament of being subject to poor quality irrigation water as well as damage to their health and livestock. In addition, discussion with officials of Department of Agriculture, Government of Karnataka, Pollution Control Board and the University of Agricultural Sciences, Bangalore, regarding soil and water quality analysis indicated that the agricultural incomes of the farmers of the area are affected due to poor groundwater quality despite the proximity to Kabini command canal water being used for irrigating paddy and /or sugarcane crops by farmers. Therefore, the study area was chosen to value the economic losses to farmers due to the use of groundwater affected by the distillery effluent in Nanjangud taluk, Mysore district (Figs. 1 to 11). The primary survey was conducted during December – January 2002-03. For this study, a sample of 35 farmers located in the four distillery effluent polluted area (DEPA) villages viz., Geeka halli, Goluru, Mulluru, and Kodi Narasipura, which had surface water irrigation from kabini command, and 35 farmers in two (control) villages, Devarasanahalli and Horalawadi which were not affected by distillery effluent which also had surface water irrigation from Kabini command (as control) were studied.

Sampling design

The distillery began its operations of manufacturing ethanol from sugar cane in 1985. The molasses, which is a raw material for manufacture of ethanol and baggase for fuel, were purchased by the distillery from Bannariamman sugars in proximity. In 1985 the farmers in the vicinity of the distillery gave no objection for opening the distillery. The state pollution control Board also cleared the establishment of the factory with the necessary condition of treatment of effluents according to prescribed standards. The farmers owning irrigation wells even though started noticing the discoloration of their groundwater from their wells, were initially at a confusion regarding the reasons for the discoloration. The discoloration of the groundwater began during 1995 when farmers felt the effect of damage. From 1995 a few farmers began approaching the authorities like Agricultural officer, District Commissioner and the Pollution Control Board to solve this predicament. Obviously the farmers were among those who were not employed by the distillery, as they did not receive co-operation from the farmers who are employed. In Dec 2001 the matter was reported to the Lokayukta who visited affected farmers (Fig 6) and the distillery and gave decision to close the distillery as it was found to have damaged the aquifer and in turn affected their farm incomes. The State Pollution Control Board, Bangalore (SPCB) and the soil and water testing unit of Agricultural department, Nanjangud was directed by the Lokayukta to report on the quality of groundwater for irrigation, for domestic purpose including drinking purpose. The choice of affected farmers is based on the reports of both Pollution control Board and Agricultural Department. In the DEPA there were 64 irrigation wells located in the area of influence of the distillery in question. According to State Pollution Control Board 67 per cent of these wells (43) are polluted due to the distillery effluent seeping to the aquifer. All 35 farmers owning these 43 wells have been chosen for detail study. The other 33 per cent of wells (21) were also polluted but the level of pollution as indicated by Electrical Conductivity, pH and other associated parameters are in the acceptable pollution limits for irrigation. The SPCB analyzed EC, pH, sodium, chloride, sodium absorption ratio, calcium, as indicators of groundwater quality during Dec 2001. For contrast, another sample of 35 farmers from the adjacent villages whose groundwater was not polluted, located in the Kabini command area was selected as control.

<u>Database</u>

Primary data were collected from farmers for agricultural year 2002-03 through pre-tested structured schedule. Secondary data on groundwater quality were obtained from The Karnataka State Pollution Control Board, Bangalore and Agricultural Department of Nanjangud taluk.

Yield of irrigation well

Bore well was the predominant water extraction mechanism in distillery effluent polluted and control villages. In the DEPA, among 38 functioning wells, 31 are bore wells. In the control village among 37 wells, 28 were bore wells. Field measurements of the yield of wells were taken for dug wells and borewells. Farmers were asked to indicate the height of water column of the dug well which would regain within over night of pumping. For round shaped dug wells, volume of water was estimated as ($\pi * r^2 * h$), where, r = radius of the dug well (in feet). For dug wells which are rectangular in shape the volume of water was estimated as (l*b*h) where l=length of well, b=breadth of well and h=height of water column regained in 12 hours in feet. The resultant volume of water in cubic feet was converted to gallons by using the conversion, 1 cu ft = 6.2288 gallons. Finally, the yield of water in gallons per hour (GPH) from the dug well is given by the formula, $(l*b*h*6.2288)\div12$ or $(\pi * r^2 * h* 6.2288)\div12$.

Yield of bore well was measured by recording the number of seconds to fill a bucket of water of 15 liters capacity. This was linearly extrapolated to obtain the groundwater yield in gallons per hour. The yield of bore well in liters is then converted to gallons per hour by using conversion of 4.5 liters =1 gallon.

<u>Estimation of externality</u>

Farmers of the study area are located in the tail end region of Kabini irrigation command. They have invested in irrigation well, since they have not assured water availability throughout the year in consonance with their crop pattern being single crop of sugarcane or two crops of paddy.

However, in the study area, due to ineffective monitoring and implementation of water pollution control law, a distillery is letting in its effluents in a few massive unlined (or recently lined) lagoons and in several unlined lagoons. Given that the soil is red loamy and well drained, the groundwater in 67 percent (i.e. in 43) of 64 irrigation wells is fully polluted due to distillery effluents. As the farmers have no alternative other than using the polluted groundwater for irrigating during lean season, they are incurring economic losses, an externality due to use of poor quality groundwater for irrigation. Two different measures of externality (i) difference in the amortized cost of irrigation between farms located in good quality groundwater area (control) and poor quality groundwater area (DEPA) and (ii) difference in the net returns between control and DEPA. The first measure captures mainly the externality from (a) receding groundwater level and (b) forced expenditure on irrigation pump sets due to pumping poor quality groundwater. The irrigation pump sets and accessories get corroded fast due to pumping the effluent groundwater. There are several cases of farmers reporting heavy repair expenses even to the tune of Rs. 2500 per year (ranging from Rs. 500 to Rs. 2500) due to effluent groundwater.

The second measure captures comprehensive externality cost due to poor groundwater quality in agriculture due to *ceteris paribus* conditions. This measure subsumes the first measure of externality caused due to pumping distillery effluent groundwater corroding the pump set and accessories.

Additional expenditure on maintaining health due to exposure to distillery effluent groundwater

Farmers in the DEPA are frequently affected by skin allergies, headache, vomiting sensation, irritating eyes, fever and stomach pain. Avertive expenditure on health included treatment cost, cost of medicine and the opportunity cost of labor in terms of loss of labor wage due to sickness. Human health externality is calculated as the difference between the health expenditure per capita in control village and DEPA.

Additional expenditure on maintaining animal health due to exposure and consumption of distillery effluent groundwater

Farm animals cannot be controlled from their free movement, free grazing and consumption of water available in ponds, streams. Cattle were seen drinking the distillery effluent groundwater. According to farmers this has resulted in increased livestock mortality, poor health, and reduced milk yield. Animal health externality is the difference between the health expenditure per animal in control village and DEPA.

RESULTS AND DISCUSSION

This study deals with estimation of negative externality faced by farmers in agriculture, human and livestock health due to groundwater pollution externality imposed by distillery in Nanjangud taluk, Mysore district. The results include inter alia, socio economic characteristics of farmers, economic features influencing their decision-making in the wake of groundwater pollution externality and their struggle to be resilient with regard to the predicament of poor groundwater quality. In the presentation the features are compared between the farmers of DEPA (Distillery Effluent Polluted Area) and farmers of control area.

Family size and other socio economic features

Sample for this study included the population of all the 35 farmers whose wells were affected by distillery pollution in DEPA (Geekahalli, Goluru, Mulluru and Kodi Narasipura) and a sample of 35 farmers in the control village (Horalavadi and Devarasanahalli in Najnangud taluk). The average family size is around 6, with half of them each representing male and female members and do not vary between DEPA and control situations. About 66 percent of family members are involved in agriculture in both the situations. The average size of holding is 6.17 acres per family in DEPA and 7.4 acres per family in control area. In both situations, at least 90 percent of the holding size is irrigated, as the villages are located in the Kabini command area. (Table 1)

Class of the sample farmers

In control village about 63 percent of the sample farmers are large farmers where as in DEPA 52 percent of farmers are large farmers. There are no marginal farmers in the sample in control village; while 11 per cent are marginal farmers in DEPA. (Table 1)

Non-farm income

Only about 50 percent of the family members depend on agriculture in polluted area where as about 75 percent of the family members depend on agriculture in control village. This is because in the polluted area the return from agriculture is reducing due to effect of pollution. So the farmers tend to retire from agriculture and engage in other non-farm activities. The income from non-farm source is higher in DEPA per family (Rs.11,142) compared with control village (Rs 3,571). This works to Rs. 1805 per acre in DEPA and Rs.485 per acre in control village. This is a pointer to the fact that due to under employment caused by DEPA; farmers are engaging in higher non-farm income generating opportunities, compared with control village situation. About 50 per cent of the farmers are employed in the factory. The distillery is using a political economy strategy as it is employing 50 per cent of the farmers at the rate of one per family whose wells have been polluted beyond threshold limits for irrigation and therefore in DEPA the non farm income per family is higher than that in control village. Even then this works out to an approximate wage of Rs 35 per day, which is much below the going wage rate of Rs 60 per man day and Rs 40 per woman day. (Table 1)

Change in cropping pattern before and after pollution

In the distillery effluent polluted area (DEPA) there is noticeable change in cropping pattern due to pollution. In DEPA farmers were able to grow paddy and sugarcane, which are high water user crops before pollution since the area was irrigated by kabini right bank canal for about 7 months from June to December. The farmers had protective irrigation from their groundwater through open and bore wells in the seasons when canal water was not available. But after the pollution of their groundwater, it has become difficult for the farmers to irrigate sugarcane, which is annual crop when canal water was not available for irrigation. So area under sugarcane drastically reduced from 52 per cent to 30 per cent to the total cultivated area but area under paddy remained unaltered, thus giving an indication that sugarcane is relatively sensitive to distillery pollution than paddy crop.

The farmers in the distillery effluent polluted villages are trying alternative cropping pattern, which can thrive only with canal water and under poor water quality. The area under ragi, mulberry, tomato and jowar increased after pollution replacing sugarcane as these crops consume much lower groundwater when compared to sugarcane. Vegetables are mainly grown, as they are short duration crop and as the village is near to Nanjangud town it can fetch good price for farmers. In addition have reduced the exposure of soil and aquifer from 12 months to 3 months. Since the farmers cultivate vegetables for 4 months. Mulberry though a perennial requires only 25 per cent of water consumed by sugar cane and is hardier. The pollution till date has affected the yield and not the quality of the produce. So the price is not affected due to pollution. Thus, crop and income diversity increased after pollution (Table 2) as a coping mechanism.

Crop pattern in control village

In control village, paddy and sugarcane are predominant cropping pattern due to availability of good quality of water throughout the year. Sugarcane occupies about 132 acres of total cropped land, forming 51 per cent of total cropped area. Paddy is cultivated in 52 acres, forming 20 per cent of total cropped area (Table 3). Only 4 per cent of the total cropped area is occupied by ragi, which is for staple food for the household. Vegetables and other crops occupied a meager portion in the total cropped area.

Details of all wells in DEPA

As DEPA is located in the tail end of Kabini irrigation command, and as farmers continue to cultivate water intensive crops like sugarcane and paddy, they find water scarcity during summer months of Jan-June every year. In order to substitute for surface irrigation in lean months, farmers have drilled irrigation wells. In this area, after the advent of distillery in 1985, the irrigation wells drilled became gradually polluted. Farmers who were applying good quality groundwater from Jan to June and good quality surface water from July to Dec, are now applying poor quality groundwater from Jan to June due to pollution inflicted by the distillery, and the SPCB(State Pollution Control Board) has declared this groundwater as unfit for irrigation.

Chemical Tests of Groundwater quality

The quality tests of groundwater from the wells in DEPA have indicated pH, Electrical conductivity (EC) and sodium concentration of groundwater exceeded permissible limits of irrigation. It is in order to note that initial and premature failure of irrigation wells in hard rock areas is becoming widespread leading to intertemporal externalities in well irrigation. In the study area, as the irrigation wells are located in the Kabini irrigation command area, there has been virtually no failure of irrigation wells. In DEPA, all the three drinking water bore wells have been totally abandoned as the quality of water exceed the permissible limits of drinking water. Here the quantity of water is not the main problem but quality plays an important role. But here the farmers have not incurred transaction cost in fetching drinking water as the Distillery unit responsible for polluting groundwater is voluntarily pumping water from the nearby Suvarnavathi river (tributary of Kabini river) and storing them in three water storage structures. Villagers fetch water from these structures every day, thus saving the cost of labour, which they would have incurred in the absence of such a water supply. Farmers in DEPA abandoned five irrigation wells (12 percent) out of 43 wells, as they could not use the groundwater due to pollution. The water from the remaining 38 irrigation wells has also recorded high levels of pollution parameters. This is further polluting the soil and the aquifer through return flows. The soil microbial activity is at stake as it is affected by the distillery effluent affected groundwater. Among 9 open wells farmers have abandoned 2 wells, which has lead to 22 per cent decrease in open well. Only 31 out of 34 bore wells are used for irrigation after pollution. (Tables 4A and 4B)

Effect of distance from lagoon and canal on economic parameters

Lagoon is a huge structure built to store the spent wash (Fig 5), which is a waste product from distillery factory. As in the study area, the lagoon built 15 years back was not cement lined. As a result the harmful effluents percolated in to the soil polluting soil as well as groundwater. The intensity of pollution is greater in the wells, which are nearer to lagoon. Hence the effect of distance from lagoon on different economic parameters is studied in particular along with the effect of canal distance to the wells.

The effect of distance from lagoon and canal on farm economy was estimated by sorting data with the distance from lagoon and canal. Accordingly, the distance was divided into proximal (< 800 mts from lagoon) and distant (> 800 mts from lagoon), and proximal (<900 mts from canal) and distant (>900 mts from canal) based on average distance of irrigation wells of the farmers. It was found that four sample farmers in DEPA (11 percent) were proximal to both lagoon and canal, 13 farmers (37 percent) were proximal to lagoon and distant from canal, 14 farmers (40 percent) were distant from lagoon but proximal to canal and 4 farmers (11 percent) were distant from both lagoon and canal.

Effect of distance of irrigation well from lagoon and canal on amortized cost of groundwater irrigation

Farmers using distillery-polluted groundwater indicated that there expenditure on repairs to irrigation pump set increased due to corrosion of pump, pipes and accessories (Table 5). The harmful effluents which percolate in to the wells from lagoon has led to corrosion of pump set which forces the farmers to incur extra costs on frequent repairs. Repair cost is more than twice to the farmers nearer to lagoon (Rs.2516) when compared to the farmers who are away from lagoon.

However, for farmers who were distant from lagoon, but closer to canal, the repair cost was comparatively lower being Rs. 1748 per irrigation well. The pump set repair cost was the least obviously for farmers who were at a distant from lagoon and canal being Rs.937. Thus, this analysis reiterates that it is the distance of irrigation well from lagoon which influences the amount of repair cost to irrigation pump set, irrespective of how proximal or distant is the farm from irrigation canal. This has serious ramifications on the groundwater being polluted from the distillery lagoon, since even in the presence of canal irrigation and the associated seepage of surface water in red loamy soils, the effect of distillery pollution is masking the effect of dampening pollution by surface water.

Amortized cost of well does not vary much with the distance from lagoon. But apportioned amortized cost is higher to the farmers who are away from the canal (Rs.4136 and Rs.3036) when compared to near the canal (Rs.2519 and Rs.3180). As the distance of well increases from canal, amortized cost of well increases because the farmers tend to go to a greater depth, as the recharge effect from canal is absent. But overall irrigation cost is greater for the farmers who are nearer to the lagoon.

Effect of distance of irrigation well from lagoon and canal on net returns of farm

Distance from lagoon has a drastic effect on net returns of the farm. Net returns to the farmers who are distant from the lagoon but closer to irrigation canal are higher (Rs.61786) when compared with the farmers who are closer to lagoon and distant from the irrigation canal (Rs.39675). There is about 35 per cent decrease in the net returns to the farmers who are near to the lagoons (Rs. 4589 per acre) when compared to the farmers away from lagoons (Rs 6227 per acre). This is because as the distance from lagoon increases the concentration of pollution decreases which lead to increase in net return. Net return per rupee of groundwater used(amortized cost of groundwater) is lower for farmers proximal to lagoon (Rs 1102), while it was higher (Rs. 2128) for the farmers distant from the lagoon. The distance from canal has a positive impact in ameliorating the pollution effects. But it is not significant. Net returns mainly depend on the distance from lagoon. (Table 6)

Effect on cost of irrigation

The study area comes under Kabini command area. The access to irrigation is very much higher in this area. But then also gross irrigated area depends on lagoon distance. The farms that are nearer to lagoon have only 7.3 acres of gross irrigated area whereas the farms that are away from lagoon have about 12.3 acres of gross irrigated area. The reason for this is the farmers nearer to lagoon irrigate their land mainly by canal water, which is seasonal, and they are unable to use their extremely polluted groundwater.

The effect of distance from lagoon on cost of irrigation indicated that value of groundwater (amortized cost of irrigation) per acre-inch is higher (Rs. 219) since the annual repair cost is a substantial portion of irrigation cost and the groundwater used is also low at around 10 acre inches per year from the well. For farmers who were distant from the lagoon as well as irrigation canal, the cost of irrigation per acre-inch was the lowest at Rs. 19. It is in order to note that farmers with irrigation wells proximal to lagoon incurred higher cost of groundwater irrigation, since they were forced to pump lower volume of distillery polluted groundwater for irrigation. Thus, even though low water was used, its quality was in pretty bad condition, necessitating the farmers to pump out lower volume of groundwater. (Table 7)

The amortized cost of irrigation is lower for farmers whose wells are at a distance from the lagoon. For farmers whose wells are closer to irrigation canal, but are at a distance from lagoon, the amortized cost of groundwater is Rs. 58 per acre-inch. Ceteris paribus, in DEPA, if groundwater is of good quality, the value or irrigation cost per acre inch will be lower since (i) investment on irrigation well will be far lower, (ii) well failure probability is lower due to location of well in irrigation command area and (iii) higher volume of groundwater will be pumped for irrigation thereby reducing the cost per acre inch of groundwater. Thus, with increasing distance from the lagoon, the cost or groundwater reduces due to improvement in water quality, thereby pumping higher volumes of groundwater.

For irrigation wells, which are located farther from lagoon as well as irrigation canal, the cost per acre-inch of groundwater was the lowest being Rs. 19, since they used more of groundwater (69 acre inches per acre). This once again reiterates the predominance of seepage of distillery pollution polluting the groundwater, despite the presence of irrigation canal water to dissipate the distillery pollution, thereby increasing the irrigation cost, negative externalities and reducing the net returns.

Thus, the proximity of farms to lagoon seriously affects area irrigated, groundwater quality and other factors responsible for improving farm economy.

Impact on water use

Even though the farmers have access to ground water the farmers near to lagoon use only 10 acre-inches of water whereas farmers away from the lagoon is use about 69 acre-inches per acre because in DEPA gross irrigated area is also less If the farmer nearer to lagoon uses groundwater in access they are sure of loosing yield due to pollution. But the use of surface water does not vary, as there is uniform supply of canal water for all the farms. The distance from canal does not affect much on the use of water.(Table 8)

Effect on groundwater quality

Groundwater quality from irrigation wells of (sample) farms is examined with the distance from lagoon and distance from canal. Water quality is evaluated based on Salinity hazards or electrical conductivity, Sodium hazards and pH. For the water to be safe for irrigation the concentration of EC should be less than 0.75 ds/m. but in DEPA the concentration of EC in water exceeds 1 and varies up to 8 to 9 ds/m.

The sodium concentration for irrigation should be less than 10 milli equivalents per liter. But in DEPA the sodium concentration increases up to 20 meq/lt. The concentration of EC and Na are directly related to the distance of lagoon. The wells near to the lagoons are heavily loaded with the EC and Na. The concentration of EC ranges from 1.6 to 9 and that of Na ranges from 0.3 to 20 in the wells nearer to lagoon. Where as the concentration of EC varies from 0.61 to 2.2 and Na varies from 0.85 to 6.8 in the wells away from lagoon. The pH of groundwater exhibited low variability from 6 to 8. It shows a slightly alkaline pH in the water.

Here too, proximity to lagoon increased the sodium concentration in leaps and bounds and proximity to canal irrigation has not been able to significantly dampen the sodium concentration. Water quality parameters are important as it has a direct effect on plant growth; in turn it affects net returns to the farmers. Since water quality parameters exceed the permissible limits of irrigation in the wells near to lagoon, the net returns invariably decreases. (Table 9)

Impact on human health

The villagers in DEPA have been suffering from various diseases arising out of water pollution such as skin allergy, dermatitis, and stomach pain. Due to foul smell from the distillery people also suffered from vomiting sensation, headache, irritating eyes. Majority of complaints are about the problem of lung disease and extreme weakness. It is found that three people in the village have been paralyzed due to drinking water contamination. This has led to severe psychological and economic pressure on the families. People are exposed to the toxic chemical water while working in the farm. The additional expenditure on health care per annum increased steeply for affected farmers. In terms of increase in the number of visits to doctor per month per family was four visits in the case of distillery effluent polluted village, while in the control village it is just one visit to the doctor per month per family. The medical expense per month per family was about Rs 166 in distillery effluent polluted village while it was Rs. 45 in control village (Table 11).

Effect of consumption of distillery effluent groundwater on farm animals

Livestock is one of the main sources of income in rural areas. Since all the local water sources are polluted, livestock in the village are also facing health problems. Livestock are forced to depend on polluted water and graze on contaminated grasses. It was reported by the villagers that 17 cattles died after drinking polluted water during one year (2002-03). Majorities of cattles have fallen sick over the years. There is about 44 per cent reduction in milk yield in the local cattle where as about 50 percent reduction in crossbred cattle when compared with the control village.

The main health problem faced by the cattles are dehydration in cattle due to feeding green fodder grown with polluted water. The medical expenditure incurred by families in DEPA for animal health was Rs 56 per month, while it was Rs 34 in the control village (Table 12).

Conclusions

- The family size in distillery effluent polluted village is 6 in which 50 per cent of the family members depend on agriculture. In control village, the family size is 7 and 75 per cent depend on agriculture.
- The non-farm income per family per annum is higher in distillery effluent polluted village (DEPA) (Rs 11142) compared to control village (Rs 3571).
- Area under sugarcane drastically reduced from 52 per cent to 30 per cent of total cultivated area in DEPA.

- Area under paddy did not alter after pollution. Thus, farmers considered paddy to be the only crop which can tolerate / withstand, pollution levels.
- Crop diversity increased after pollution in DEPA. Area under crops like tomato, ragi, jowar, cucumber and banana increased.
- In control village major crops are paddy and sugarcane due to assured supply of good quality of water through out year, which occupy 20 per cent and 50 per cent of the area respectively.
- Majority of wells in both polluted and control village are bore wells.
- All the drinking wells are abandoned due to pollution in distillery effluent polluted village. In addition, 22 per cent of open wells and 8.8 per cent of bore wells are abandoned, as it could not be used for irrigation.
- Even with accessibility to irrigation, cropping intensity and irrigation intensity in distillery effluent polluted village is 174 per cent and 156 per cent respectively which is lower when compared with the control village (the additional health care expenditure incurred was Rs 1992 per family per 196 per cent and 220 per cent respectively)
- Farmers using poor quality groundwater incurred an irrigation cost of Rs 28.35 per acre inch per which is twice compared to control village (Rs 13) per acre inch due to increased cost of repairs and maintenance of pumps set due to corrosion induced by pumping distillery effluent polluted groundwater.
- Application of distillery effluent polluted groundwater for irrigation has resulted in farmers to incur huge losses in terms of net return per farm (Rs 50, 480) which is less than half of the net return received by farmers in control village (Rs 137850).
- The farmers applying poor quality groundwater incurred a loss of 5 qtls of paddy yield when compared with farmers applying good quality water.
- Farmers in DEPA had to incur a considerable amount as irrigation cost which is about 15 per cent of the total cost of production of paddy where as in control village only 9 per cent is used as the irrigation cost in total cost of production.
- Farmers realized net return from sugarcane of Rs 2954 per acre cultivated using poor quality irrigation water as against Rs 26,249 realized by applying good quality groundwater.
- The use of polluted groundwater resulted in allergic dermatitis, skin irritation, vomiting sensation, stomach pain and irritation of eyes. Due to this annum.
- There was an increase in the rate of cattle mortality due to consumption of polluted groundwater by cattle. About 17 cattle died in DEPA as against six cattle in control village. Milk yield reduced by 50 per cent. Due to skin rashes, edema and dehydration, the farmers had to incur a medical expenditure of Rs 156 per family per month.
- The repair and maintenance cost of pump set has increased twice to the farmers whose wells are situated near to lagoon (Rs 2500) as compared to the farmers away from lagoon.
- Net return per farm for farmers located away from lagoon increased by 35 per cent (Rs 6227) when compared with farmers near the lagoon.
- Irrigation cost reduced with increase in distance from lagoon. Irrigation cost incurred by farmers closer to lagoon was Rs 219 per farm while it was Rs 19 for farmers away from lagoon.

- Due to use of polluted groundwater productivity of all crops reduced in distillery effluent polluted village. There was a 49 per cent decline in sugarcane yield, 27 per cent in paddy, and 75 per cent reduction in yield of tomato.
- The loss of human labour days due to health damage resulting from distillery pollution was about 18 days. As a result the farmers incurred an opportunity cost of Rs 900 per annum.
- Distance from irrigation canal was negatively associated with net return per rupee of groundwater cost. Thus, as the distance from canal increases the net returns decreases. This shows that the canal water helps in ameliorating pollution hazards but not to a significant effect. The electrical conductivity is also negatively related to net returns showing that as the EC increases the net returns decreases.
- The farmers using polluted groundwater for irrigation incurs a net loss of about Rs 19077 per acre of sugar cane production and about Rs 4767 per acre of paddy production.

Policy implications

- Polluters pay principle should be used to account the polluters’ inaction in reducing / preventing pollution.
- The Karnataka State Pollution Control Board should enact strict policy framework to prevent pollution.
- Subsidies should be given to farmers to take up amendments to control pollution damages. Suitable amendments like application of gypsum, green manure should be employed to reduce the effect of pollution on soil.

Table 1: Socio economic indicators of sample farmers in DEPA* and control **village, Nanjangud taluk, Karnataka (2002)**

Particulars	**Distillery effluent polluted area (DEPA)**	**Control village**
1. Family size	6	7
2. Male	3	3
3. Female	3	4
4. No of persons depending on agriculture per family	4	5
5. Holding size (acres)	6.17	7.4
6. Rain fed area (acres)	0.45	0.82
7. Irrigation area (acres)	5.71	6.57
8. Proportion of different categories of farmers		
a. Marginal farmers	11	0
b. Small farmers	37	37
c. Large farmers	52	63
8. Non farm income per family	11142	3571

*Note: * - Distillery Effluent Polluted Area*

Table 2: Cropping pattern before and after pollution in DEPA in Nanjangud taluk, Karnataka (2002)

Crops, season wise	Before pollution of well (1995)		After pollution of well (2002)	
	Area (acres)	Percentage to total	Area (acres)	Percentage to total
Kharif				
Paddy	49	22	46	21
Cotton	2	0.9		
Ground nut	3	1.3		
Tomato			12.5	5.9
Ragi			18	8.5
Jowar			5	2.3
Cucumber			2.5	1.2
Onion			1	0.47
Annual crops				
Sugar cane	113.5	52	64.5	30
Banana	10.5	4	10.5	5
Perennials				
Coconut	38	17.5	40	19
Mulberry			10.5	5
Fallow			5.5	2.3
Total	216		210.5	

Table 3: Cropping pattern of DEPA and control village in Nanjangud taluk, Karnataka. (2002)

Crops, season wise	Distillery effluent polluted area		Control area	
	Area (acres)	Percentage to total	Area (acre)	Percentage to total
Kharif				
Paddy	46	21	52	20
Tomato	12.5	5.9	2	0.7
Ragi	18	8.5	10.5	4
Jowar	5	2.3		
Cucumber	2.5	1.2		
Onion	1	0.47		
Beans			9	3.4
Annual crops				
Sugar cane	64.5	30	132	51
Banana	10.5	5	3	1
Perennials				
Coconut	40	19	47.5	18.3
Mulberry	10.5	5	1	0.3
Fallow	5.5	2.3		
Total	216.5		258.5	

Note: *Water from canal flows from June to December, groundwater from wells is used in other period*

Table 4A: Details of sample wells in DEPA in Nanjangud taluk, Karnataka (2002)

Particulars	Before distillery effluent pollution	After distillery effluent pollution	Percentage of wells abandoned*
No of open wells	9	7	22
No of bore wells	34	31	8.8
Total no of wells	43	38	11.6
Total no of drinking wells	3	0	100

** All the wells are functional but some of the wells are abandoned due to exceeding permissible limits for agriculture*

Table 4B: Details of wells in control area in Nanjangud taluk, Karnataka (2002)

Particulars	Wells
Number of open wells	9
Number of bore wells	28
Total number of wells	37
Total number of drinking wells	4

Table 5: Amortized cost of irrigation and cost of repair per well in distillery effluent polluted village of Nanjangud taluk, Karnataka (2002)

Distance of irrigation wells of farmers from the lagoon storing the distillery effluents

Distance of well from the irrigation canal in Meters

	Farmers with wells located upto 800 meters from Lagoon (near to lagoon)			Farmers with wells located beyond 800 meters Lagoon (far from lagoon)		
	No of farmers with wells in this category	Repair cost (Rs. per well)	Amortized cost (Rs. per well)	No of farmers with wells in this category	Repair cost (Rs. Per well)	Amortized cost (Rs. Per well)
Farmers with wells located upto 900 meters from irrigation canal (near to canal)	4	2500 (2993 to. 2200)	2519 (3600 to 2850)	14	1748 (2080 to 1680)	4136 (4300 to 3958)
Farmers with wells located beyond 900 meters from irrigation canal (far from canal)	13	2516 (2893 to 2125)	3180 (3390 to 3956)	4	937 (1350 to 779)	3036 (3580 to 2753)

Note: The repair cost of wells for farmers located closer to the lagoon is higher (Rs. 2500-Rs.2516) as they encounter frequent repairs to their pumps than farmers with wells located far from lagoon.

Table 6: Effect of distance of lagoons and canal on net returns in DEPA Nanjangud Taluk, Karnataka (2002)

Distance of irrigation wells of farmers from the lagoon storing the distillery effluents

Distance of well from irrigation canal

	Farmers with wells located upto 800 meters from Lagoon (near to lagoon)				Farmers with wells located beyond 800 meters Lagoon (far from lagoon)			
	No	NR	NR per acre	NR per rewi	No	NR	NR per acre	NR per rewi
Farmers with wells located upto 900 meters from irrigation canal (near to canal)	4	42754 (115480.4 to 12536.13)	4589 (7345 to 2347)	1102 (3636.04 to 26.23)	14	50567 (169205 to 1685)	5620 (8905 to 4539)	2497 (13569 to 15)
Farmers with wells located beyond 900 meters from irrigation canal (far from canal)	13	39675 (155541 to 9304.9)	4526 (8904 to 3567)	1306 (4180 to 5.53)	4	61786 (143535 to 5000)	6227 (10239 to 4567)	2128 (4800.8 to 36.8)

Note:
No: No. of farmers with wells in the respective category; NR- net returns;
NR per Rewi-net returns per rupee of investment on groundwater ; NR per acre- net returns/acre of net irrigated area

Table 7: Effect of distance from canal and lagoon on cost of irrigation in DEPA Nanjangud taluk, Karnataka (2002)

		Distance of irrigation wells of farmers from the lagoon sto distillery effluents					
		Farmers with wells located upto 800 meters from Lagoon (near to lagoon)			Farmers with wells located beyond meters Lagoon (far from lagoon)		
		GIA (acres)	Amortized cost per acre inch of water (Rs)	Amortized cost per acre of gross irrigated area (Rs)	GIA (acres)	Amortized cost per acre inch of water (Rs)	Amo per a gross area
Distance of irrigation wells from irrigation canal	Farmers with wells located upto 900 meters from irrigation canal (near to canal)	7.3 (13 to 1.5)	219 (687 to 26.4)	1674 (4580 to 213.4)	12.3 (32 to 3)	58 (1269.19 to 11.8)	653 (188 170.
	Farmers with wells located beyond 900 meters from irrigation canal (far from canal)	7.9 (12 to 5)	158 (164.9 to 16.4)	784 (1267.5 to 508)	10 (14 to 7)	19 (29.8 to 9.3)	400 (607

Table 8: Effect of distance from lagoon and canal on water use in DEPA Nanjangud taluk, Karnataka (2002)

Distance of irrigation wells from canal	Distance of irrigation wells of farmers from the lagoon storing the distillery effluents: Farmers with wells located upto 800 meters from Lagoon (near to lagoon)				Farmers with wells located beyond 800 meters from Lagoon (far from lagoon)			
	No	EC	Gwu per acre	Swu per acre	No	EC	Gwu per acre	Swu per acre
Farmers with wells located upto 900 meters from irrigation canal (near to canal)	4	1 to 8	10 (12.5 to 6.6)	58 (102 to 45)	14	0.34 to 1.08	50 (79 to 38)	44 (53 to 40)
Farmers with wells located beyond 900 meters from irrigation canal (far from canal)	13	1.6 to 9	39 (54 to 32)	66 (126 to 43)	4	0.61 to 2.2	69 (84 to 60)	46 (65 to 39)

Note:

Gwu per ac- ground water used per acre for irrigation in acre inches per acre
EC- Electrical conductivity in milli eq per litre.(should be between 0 to 1 deci moles/lt)
Swu per ac- surface water used per acre in acre inches

Table 9: Effect of distance from lagoon and canal on water quality parameters in DEPA Nanjangud taluk, Karnataka (2002)

Distance of irrigation wells of farmers from the lagoon storing the distillery effluents

Distance of irrigation wells from canal

	Farmers with wells located upto 800 meters from Lagoon (near to lagoon)				Farmers with wells located beyond 800 meters Lagoon (far from lagoon)			
	No	**EC**	**pH**	**Na**	**No**	**EC**	**pH**	**Na**
Farmers with wells located upto 900 meters from irrigation canal (near to canal)	**4**	**1 to 8**	**6.45 to 7.2**	**0.35 to 14**	**14**	**0.34 to1.08**	**6.82 to 8.53**	**0.96 to15**
Farmers with wells located beyond 900 meters from irrigation canal (far to canal)	**13**	**1.6 to 9**	**6.64 to 7.41**	**0.3 to 20**	**4**	**0.61 to2.2**	**6.8 to 7.7**	**0.85 to 6.8**

Source of information: Office of the Assistant Director of Agriculture, Nanjangud, Mysore District
EC – Electrical conductivity
Na – Sodium concentration (recommended range is 0 to 10 milli eq/lt)

Table 11: Impact on human health in DEPA and control village of Nanjangud taluk, Karnataka (2002)

Particulars	Distillery effluent Polluted village	Control village	Difference
Average family size	6	7	
Number of visits to doctor per month per family[1]	4	1.3	+2.7
Medical expenses per month per family (Rs)	166	45	+121
Major types of illnesses reported	Skin allergy, dermatitis, headache, vomiting sensation, irritating eyes, fever, and stomach pain.	Fever, common cold.	

Note: This can be either four people per family visiting once, or one person visiting the doctor four times in a month

Table 12: Predicament of livestock in DEPA and control village, Nanjangud Taluk 2002

Particulars	Polluted area	Control area	Percentage difference
Cattle mortality (2002-03)	17 cattle due to effect of drinking distillery effluent polluted surface water and groundwater	6 cattle due to natural causes	+183
Major type of illness in livestock	Dehydration, skin infection, stomach infection and edema.	Dehydration	
Milk yield for local cows (Liters per cow per day	2.9	4.2	-44
Milk yield for cross bred cow (Liters per cow per day)	0.8	1.2	-50
Expenditure on cattle health (Rs per month)	56	34	+64

Note: Figures on cattle mortality is as obtained from the local Government Veterinary doctor

Fig 1: Distillery pollutant affected groundwater from borewell in Nanjangud, Mysore district, Karnataka, 2002-3

Fig 2: Dug well water polluted from distillery effluents, Nanjangud, Mysore district, 2002-3

Fig 3: Wilted plants – crop damage due to use of distillery effluent groundwater for irrigation, Nanjangud, Mysore district, 2002-3

Fig 4: Skin infection on cattle in distillery polluted water area, Nanjangud, Mysore district, 2002-3

Fig 5: Spent wash from distillery effluents stored in lagoons, polluting groundwater extensively, Nanjangud, Mysore district, 2002-3

Fig 6: Lokayuktha officials watching the distillery effluent polluted water pumped out by a farmer, Nanjangud, Mysore district, 2002-3

Fig 7: Farmer with his dead calf, due to frequent consumption of distillery effluent polluted water, Nanjangud, Mysore district, 2002-3

Fig 8: Sugarcane crop stand affected by distillery pollution affected water, Nanjangud, Mysore district, 2002-3.

Fig 9: Spent wash being transported by distillery to free delivery to distant farms convincing the farmers that the spent wash is rich in nutrients in 2002-3

Fig 10: Distillery effluent polluted groundwater pumped out of the borewell in Nanjangud, Mysore district, 2002-3

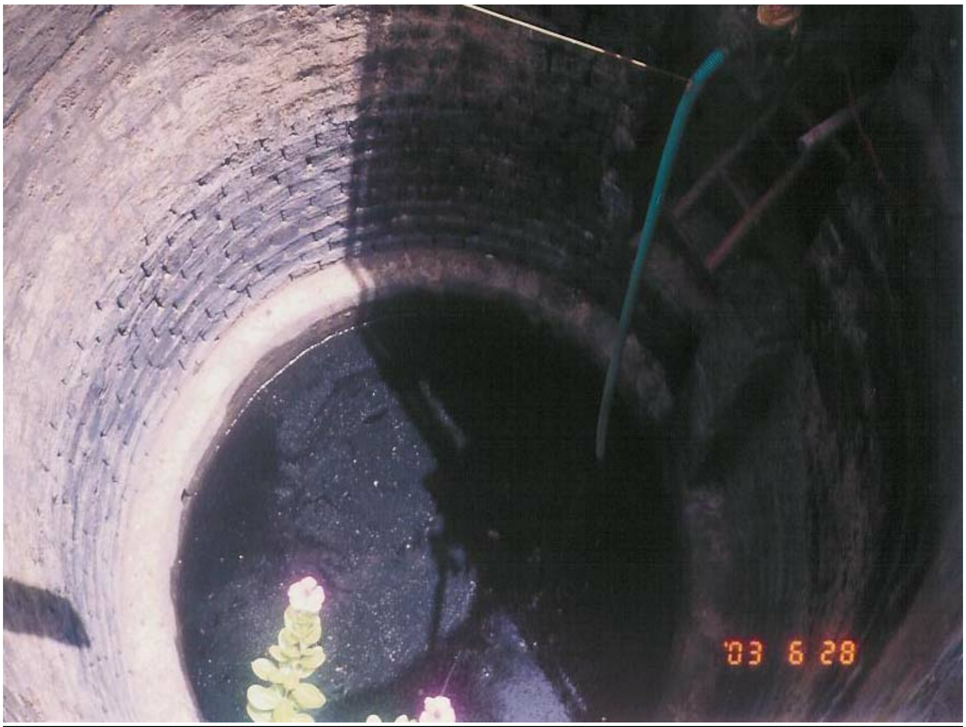

Fig 11: Distillery pollution affected dug well water in Nanjangud, Mysore district, 2002-3

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REFERENCE:

Varuni, C.N., 2003, Estimation of externalities due to use of polluted groundwater for irrigation in Kabini Command, Karnataka, unpublished M.Sc (Agri) thesis, Department of Agricultural Economics, University of Agricultural Sciences, GKVK, Bangalore 560065